Unlocking the Future of Medical Devices: Insights into Additive Manufacturing and Metamaterials

Davy Orye, Head of Additive Minds EMEA, EOS

18. September 2024

A holistic portfolio

Consulting

Material

Metal Systems

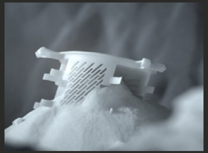
EOS M 290

EOS M 400

EOS M 400-4

EOS M 300-4

Material



Polymer Systems

FORMIGA P 110 Velocis

EOS P 396

EOS P 500

EOS P 770

EOSPRINT
Job and process management

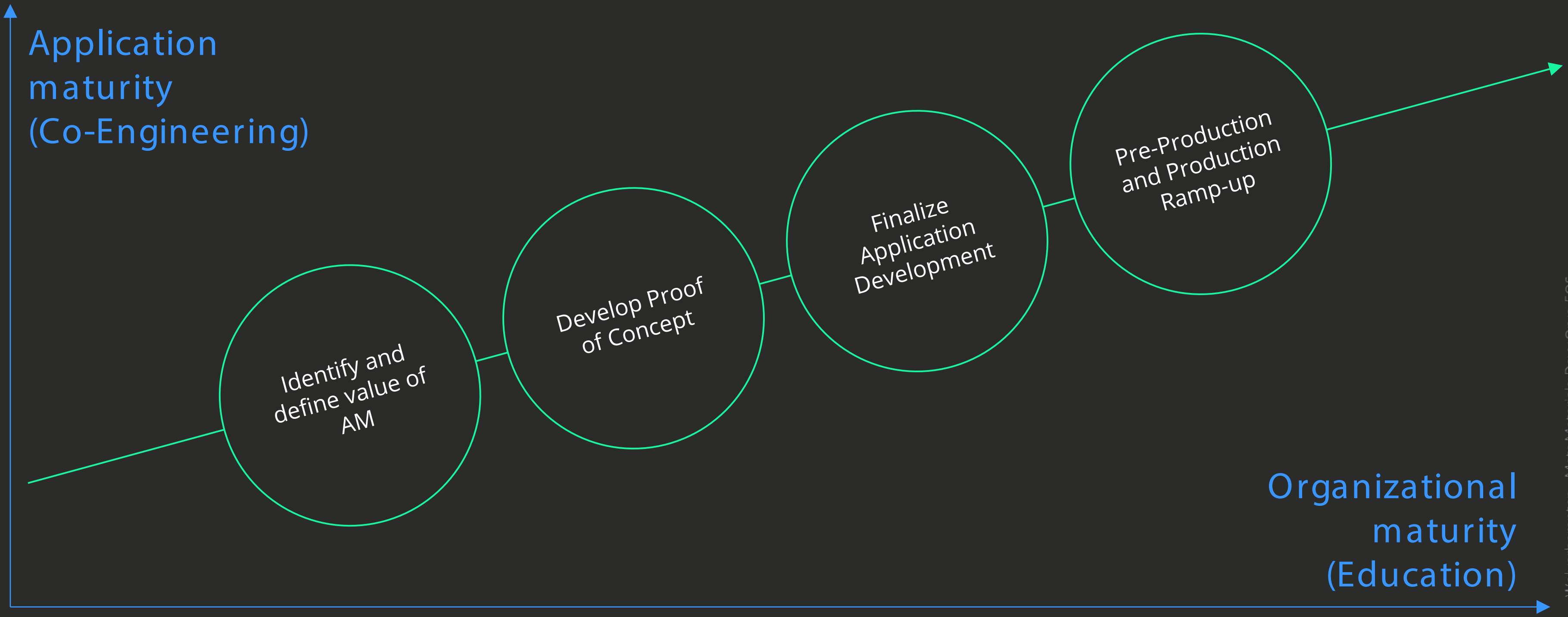
EOSCONNECT
Industrial grade connectivity

EOSTATE
Monitoring and quality assurance

Software

Wolverhampton – Meta Materials: Davy Orye, EOS

The successful Additive Manufacturing Journey – Through Co-Engineering and Education



Wolverhampton – Meta Materials: Davy Orye, EOS

Certificate programs for role based enablement

Management	Strategy		
App Engineering	Data Prep *Metal/ Polymer*	Adv. Data Prep *Metal/ Polymer*	
Operations	System Operation *Metal/ Polymer*	Adv. System Operation *Metal/ Polymer*	Self Care
Engineering	Process Eng & Science *Metal/ Polymer*	Monitoring & Smart Fusion	Design for LBPBF *Metal/ Polymer*

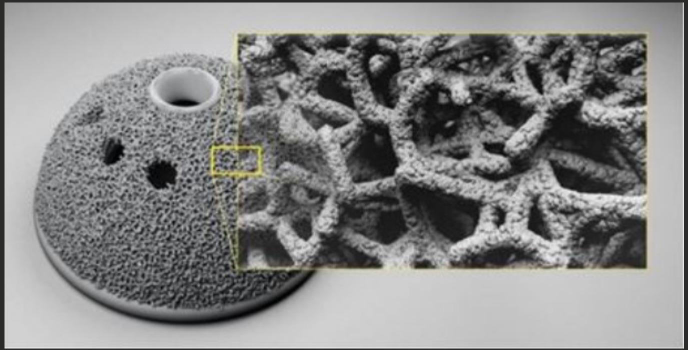
Wolverhampton – Meta Materials: Davy Orye, EOS

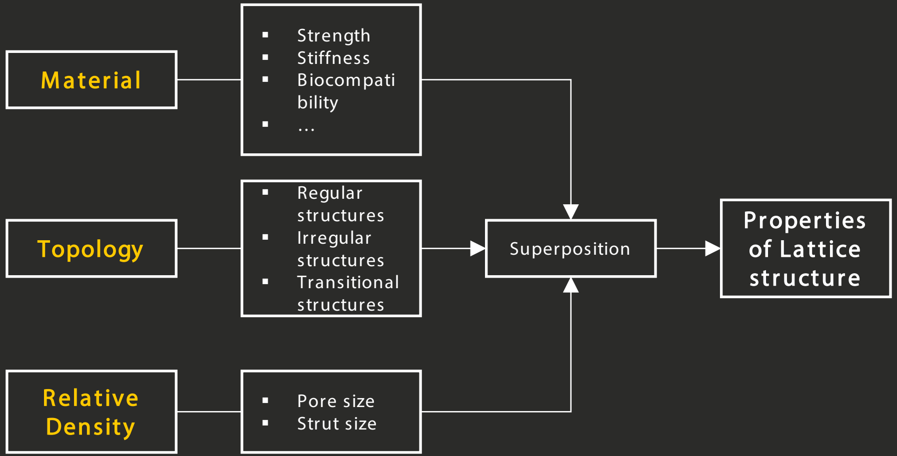
Lattice Structures in Medical

Lattice Structures

AM Enables lattice structures with **controlled geometry and properties**, leading to:

- Improved **Osseoingegration**
- Reduced **stress shielding**
- Improved initial stability
- …

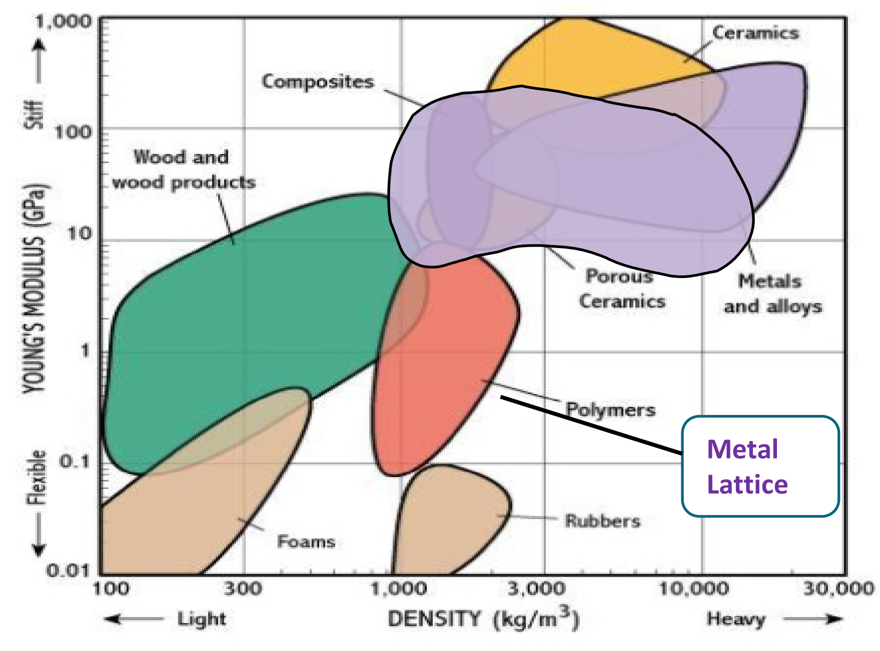




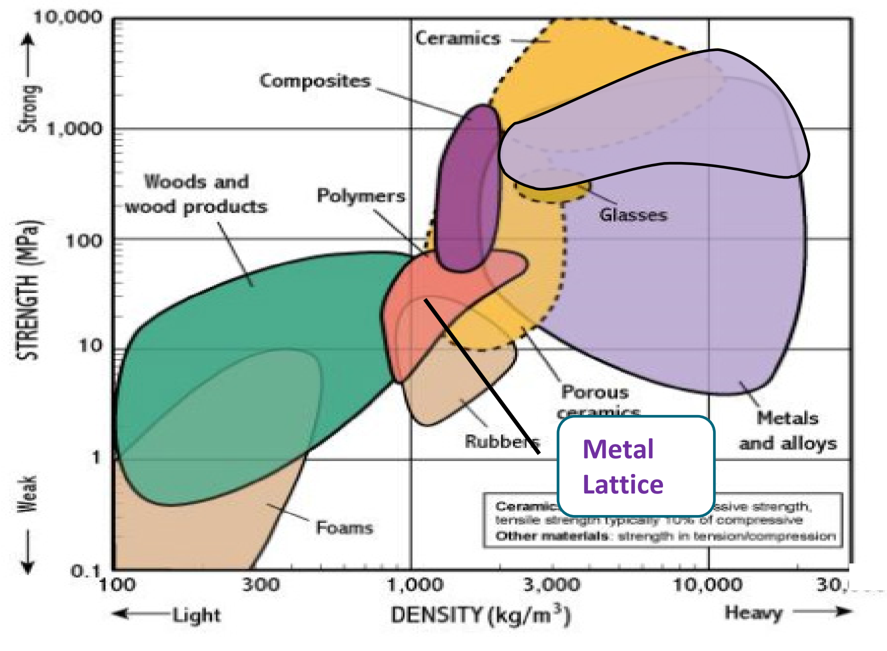
Wolverhampton – Meta Materials: Davy Orye, EOS

Creating new material properties

Ashby map – Young's Modulus



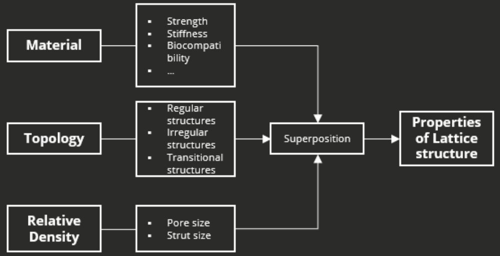
Ashby map – Strength



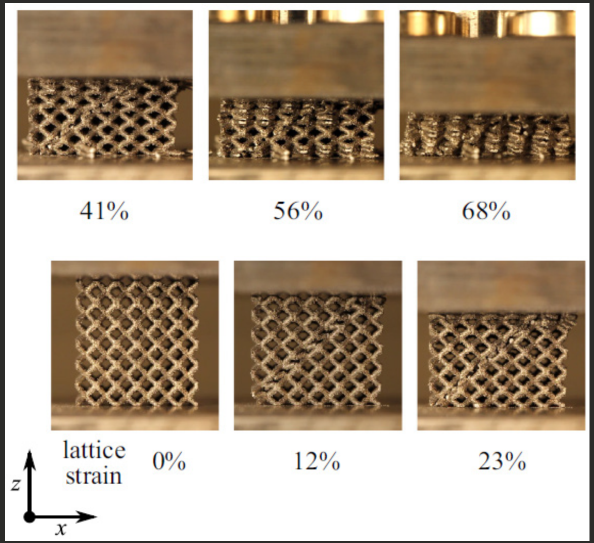
Wolverhampton – Meta Materials: Davy Orye, EOS

Lattice Structures: Materials

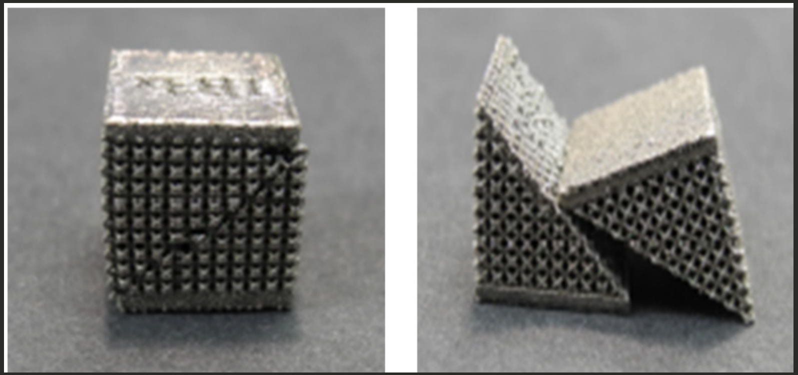
Regular Lattice Structures



Ductile materials

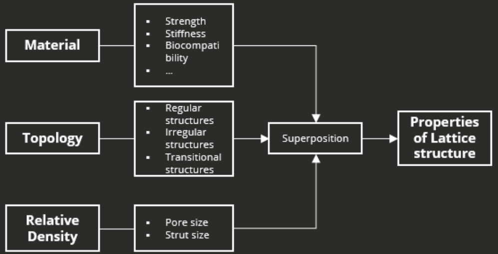


Brittle materials



Lattice Structures: Materials

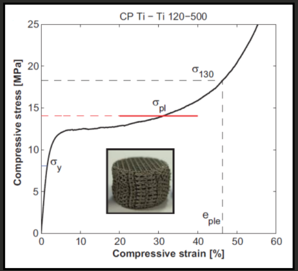
Irregular Lattice Structures



Ductile

Material & Process

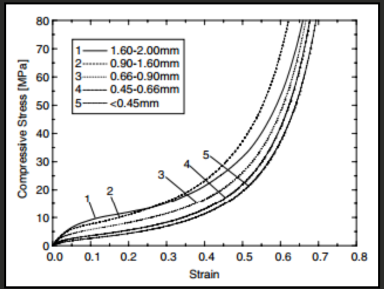
- CP Ti Lattice (DMLS)



Wauthle, R. – Industrialization of Selective Laser Melting for the Production of Porous Titanium an Tantalum Implants

Material & Process

- Pure AL Foam

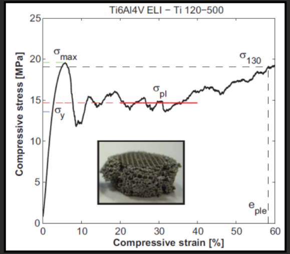


Bin, et.al. - Effect of pore size and relative density on the mechanical properties of open cell aluminum foams

Brittle

Material & Process

- Ti-64 Lattice (DMLS)



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Material & Process

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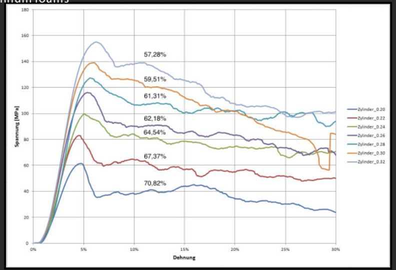


Krabusch – Untersuchung von SLM-Strukturen im Rahmen einer mechanisch optimierten Osseointegrationsstrukur

Deformable implants

AMNOVIS

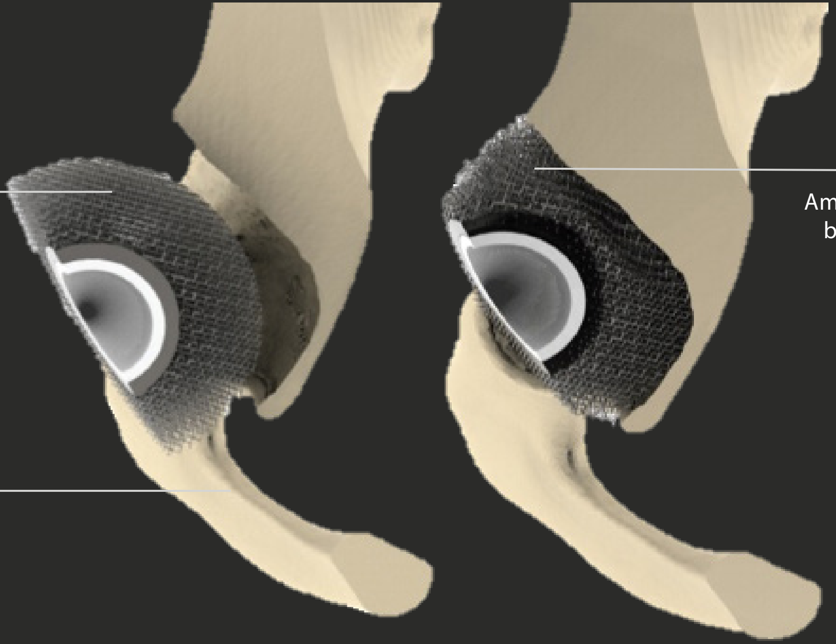
Patent pending

Pre-intraoperatively

Deformation can be done before or during the surgery, ensuring maximum flexibility

Reduced complexity

All the advantages of patient matched implants without the complexity



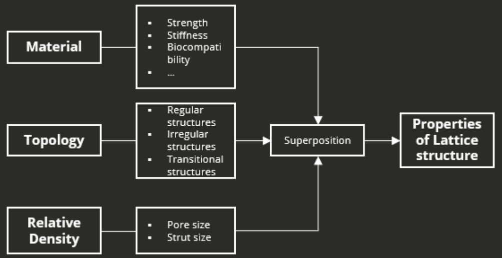
Mass Produce Malleable Shape

Amnovis CP Ti lattice is highly ductile and can be deformed to match the patient anatomy

Wolverhampton – Meta Materials: Davy Orye, EOS

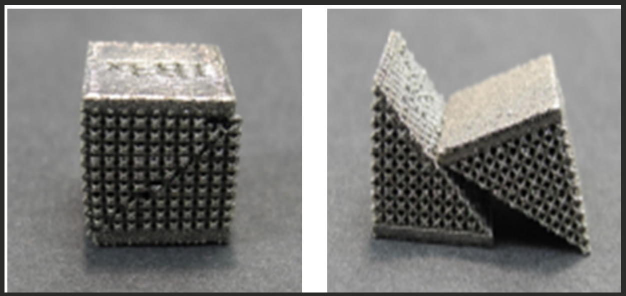
Breakage behavior depends on the properties of the material

Lattice Structures: Topology



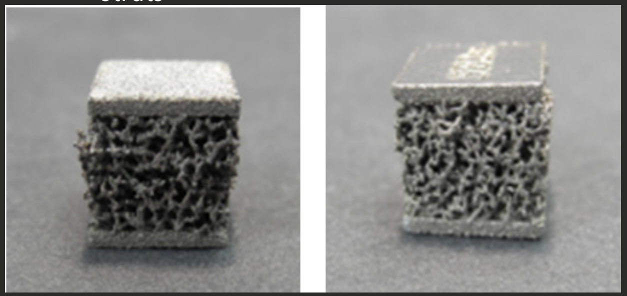
Breakage behavior of a regular structure

- Breakage starts at a certain level of stress depending on pore size and strut thickness
- Location of breakage depends on the „weakest“ strut
- Orientation of the breakage plane determines densification:
  - ➢ Horizontal plane: Densification & functionality may be ensured through tangled struts
  - ➢ Diagonal plane: No densification & no functionality



Breakage behavior of a irregular structure

- Breakage starts at different levels of stress depending on bandwidth of pore size and strut thickness
- Struts with the highest stress level start to break first (not necessarily the smallest struts):
  - ➢ Breakage of struts in different locations within the lattice (no breakage plane)
  - ➢ Densification & functionality may be ensured through tangled struts



Wolverhampton – Meta Materials: Davy Orye, EOS

Topology Optimized hip stem

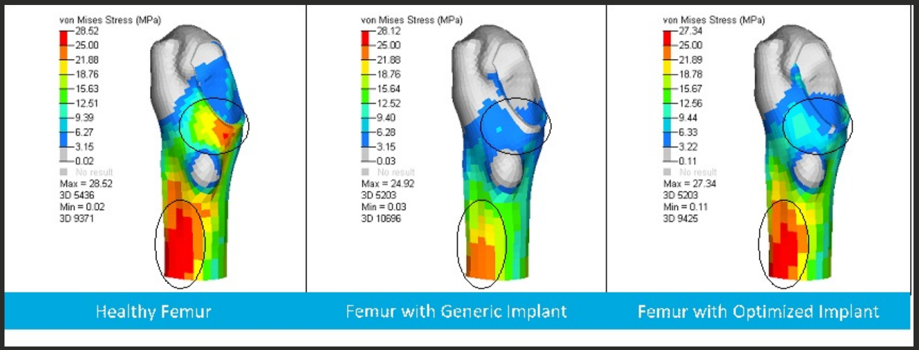
Match stiffness of bone

Topology optimized using lattice structures to mimic the stiffness variations in a femur

Rough surface

Better initial stability

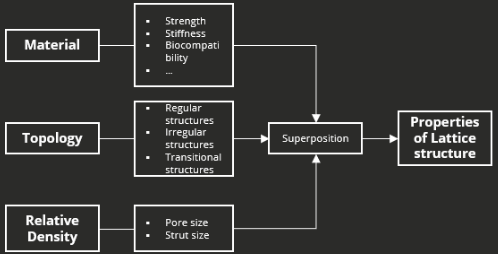
AM offers a lot more possibilities than what today is leveraged in medical devices

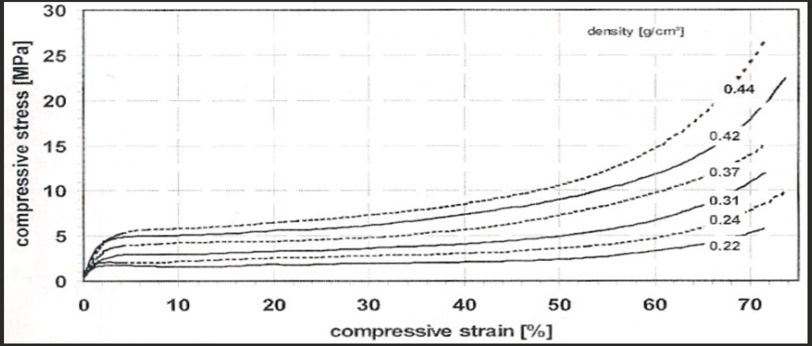


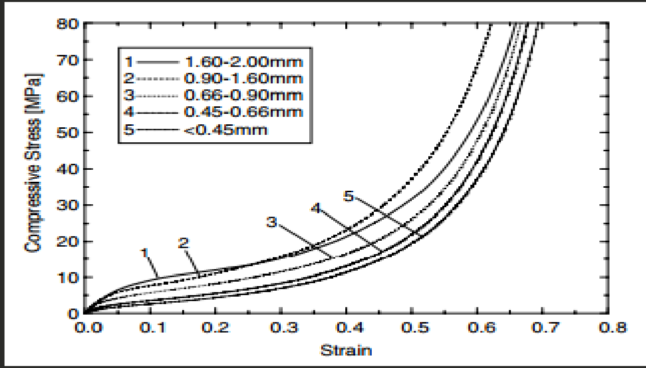
Wolverhampton – Meta Materials: Davy Orye, EOS

Source: Altair, https://altair.com/blog/articles/The-Implant-Boom-It-s-Now-Hip-to-Replace-Your-Hip

Lattice Structures: Relative Density



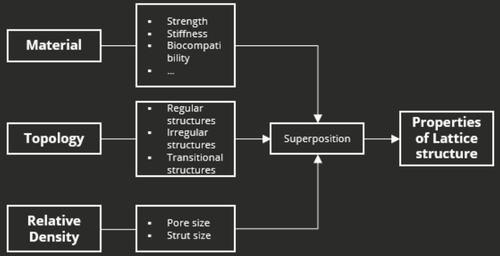




- The relative density of a lattice determines vastly the mechanical properties
- The relative density depends on the as built strut thickness, cell/pore size (and lattice type)

Wolverhampton – Meta Materials: Davy Orye, EOS

Lattice Structures: Relative Density



Gibson & Ashby-Model

$$E^*/E_s = C(\rho^*/\rho_s)^2 = C(1-P)^2$$

(Polynomial of the type of $y = ax^n$)

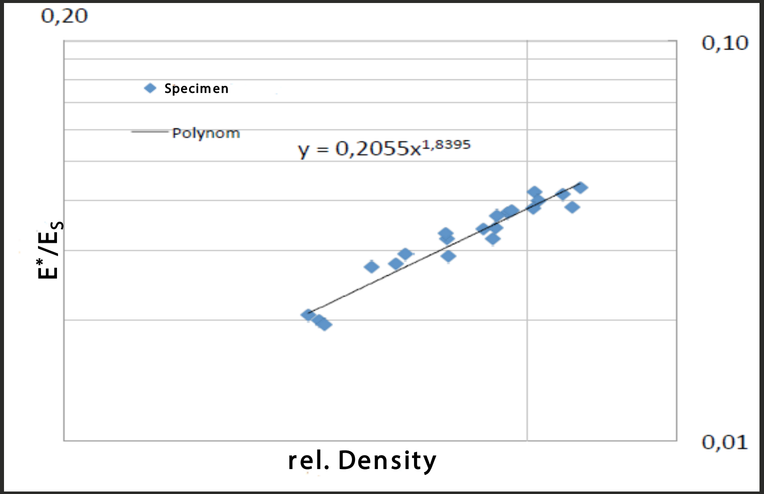
$*$: ...of latticestructure
$_s$: ...of solid

Example of an irregular lattice structure (Ti64)

$$E^*/E_s = \underbrace{0{,}2055(\rho^*/\rho_s)^{1{,}8395}}$$

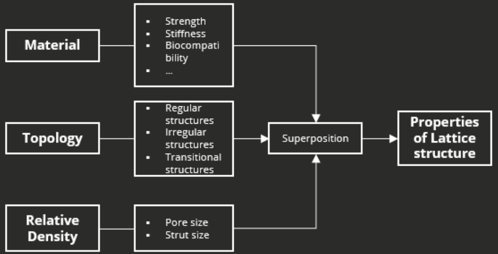
rel. Density

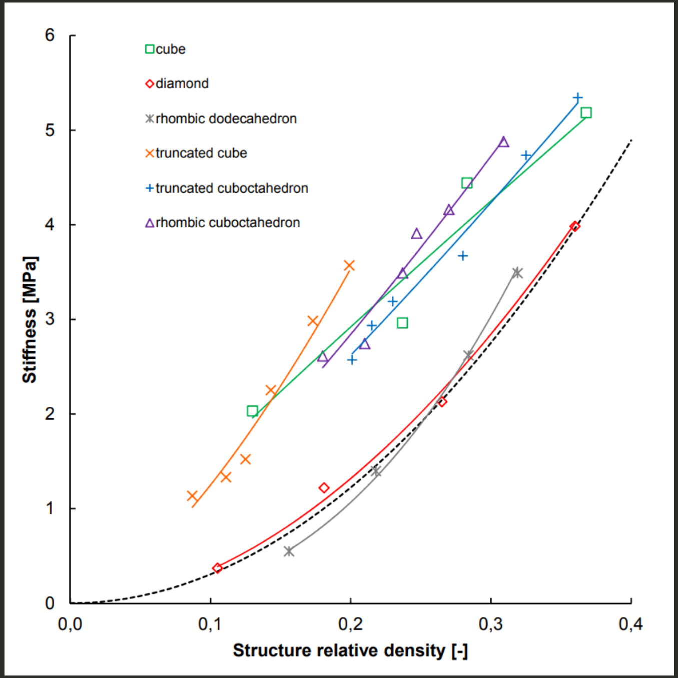
E_s = 114 Gpa
ρ_s = 4,41 g/cm^3

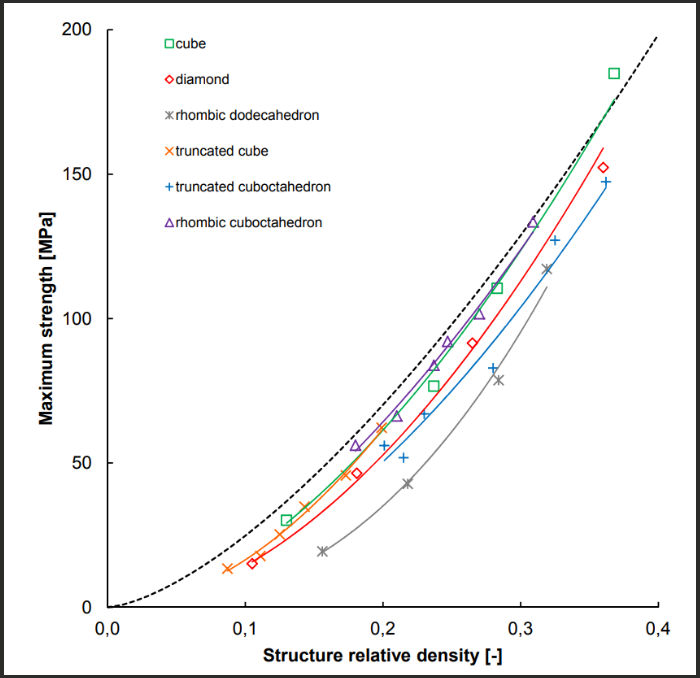


Wolverhampton – Meta Materials: Davy Orye, EOS

Lattice Structures: Relative Density







Wolverhampton – Meta Materials: Davy Orye, EOS

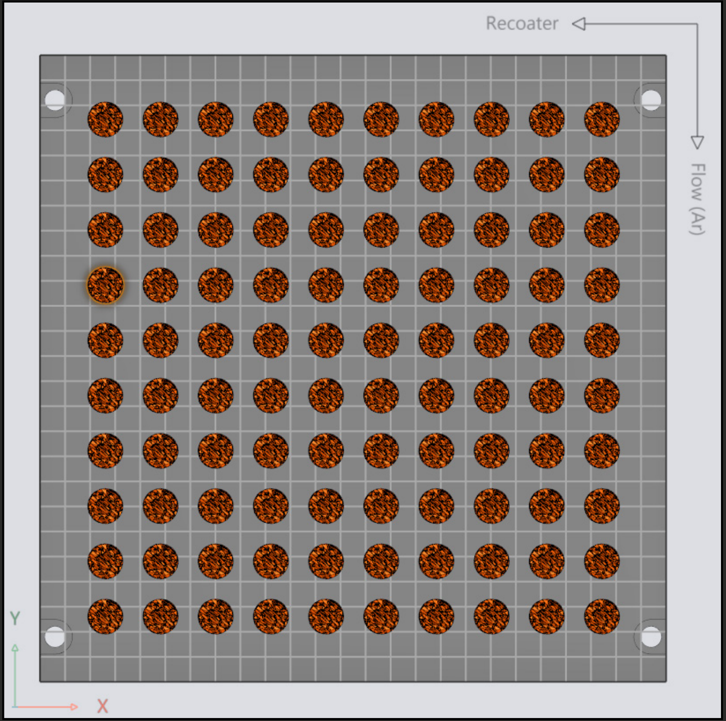
Exposure Strategies for lattice structures

Low build rate due to inefficient laser movements

Efficiency gains – lattice hatch exposure

- Simulated in Ti64, 60µm layer thickness
- 100 Cylinders with diamond shaped unit cell
- Strut thickness of 0.4mm,

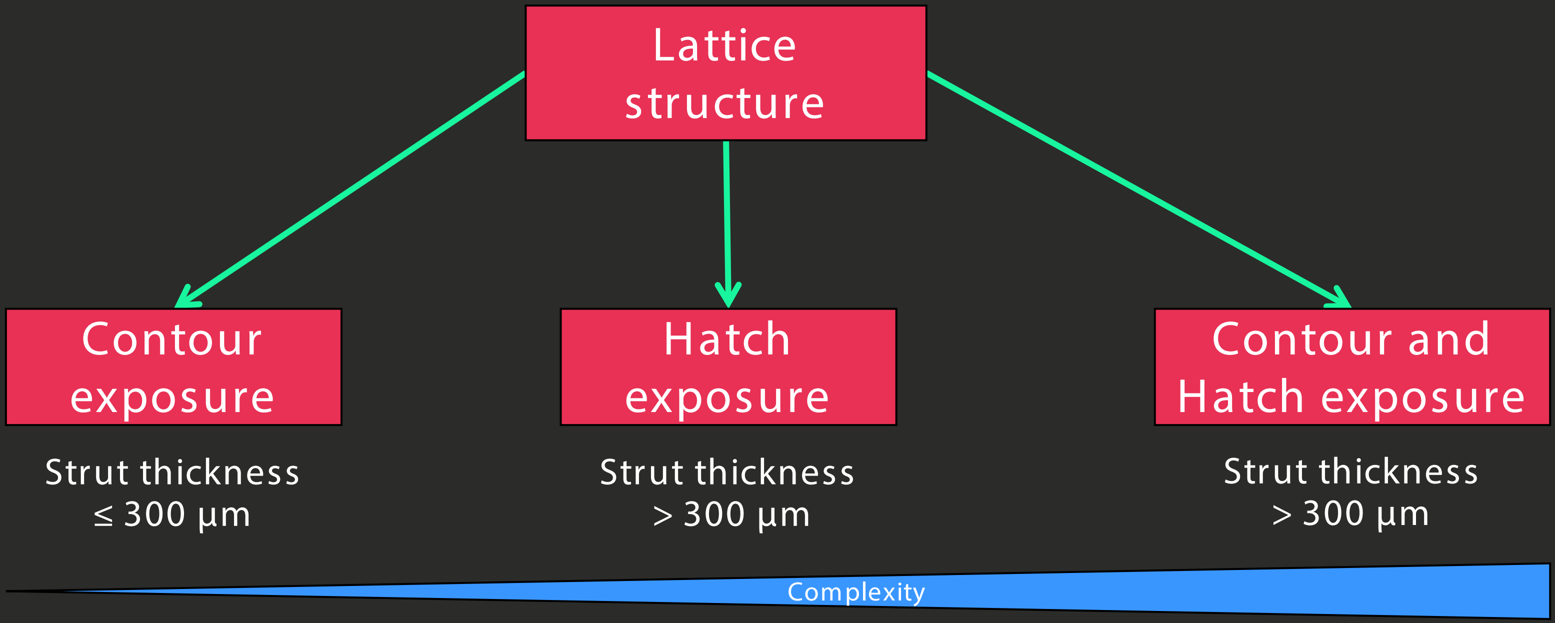
Build Time - 100 lattice cylinders		
	Build time job [min]	Build time reduction [%]
EOS_DirectPart	541	
Optimized lattice hatch exposure	180	**-66,7%**



Wolverhampton – Meta Materials: Davy Orye, EOS

Exposure Strategies

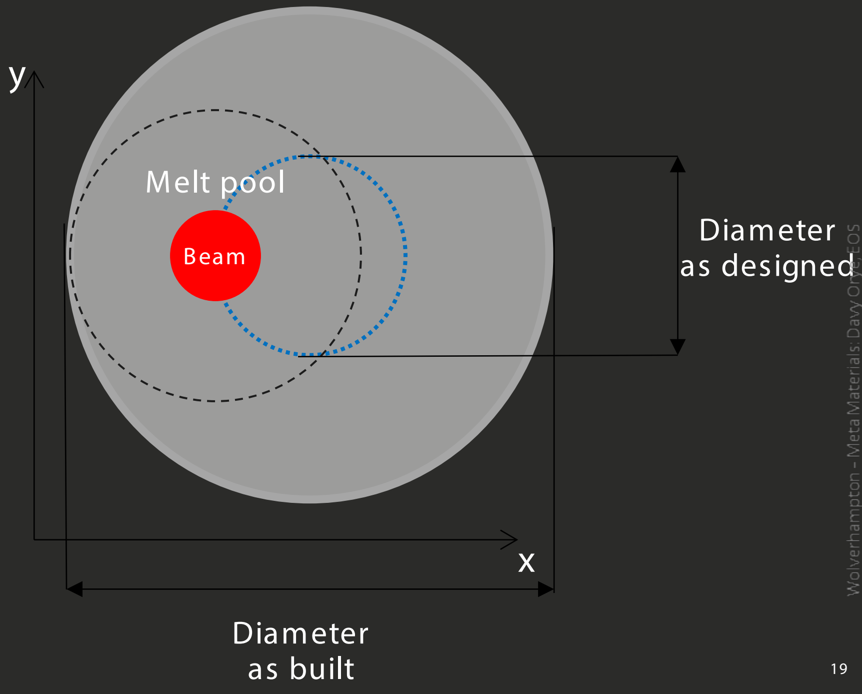
Which exposure type to use always depends on the lattice structures



Exposure Strategies

Contour exposure

- Very fast
  - No jump
  - Use size of melt pool!
- Multiple contours possible
- No up- and downskin
- Adjust design in CAD to avoid need of Global Beam Offset
  - Apply negative Contour Beam Offset
  - GBO + CBO = 0
  - Disable Edges



Exposure Strategies

Amount of Vectors

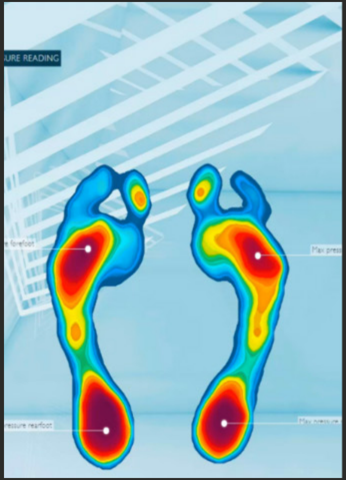
Time to scan: Shorter
Resulting Diameter: Smaller

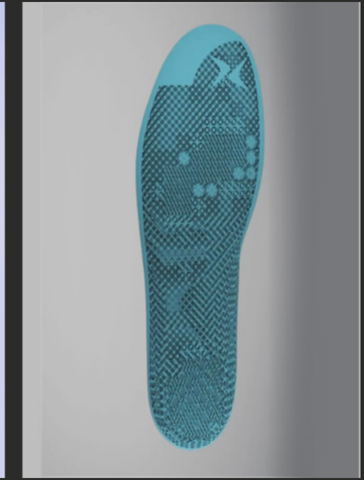
Time to scan: Longer
Resulting Diameter: Bigger

Case Studies

Digital foams

The world's most accurate custom orthotic





Aetrex Custom 3D Printed Orthotic

- Complete foot data converted into complete product – superior product
- Multiple layers of foam combined in one
- Digital Foam – truly mass customized
- Production on demand and local for local
- No inventory, no risk, low cost

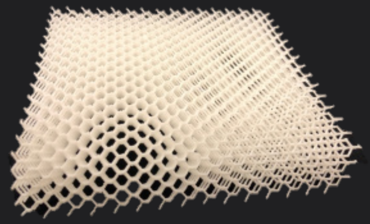
Wolverhampton – Meta Materials: Davy Orye, EOS

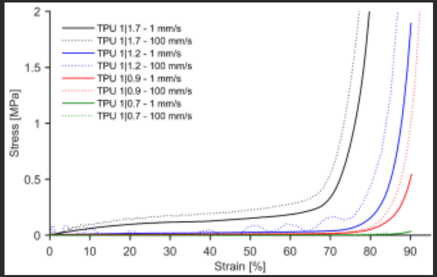
Types of Foam

Stress-Strain Results For Protective Foam

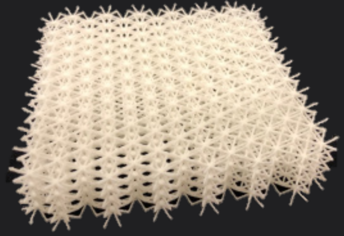
Overall TPU has a **small strain-rate dependency** relative to other polymers

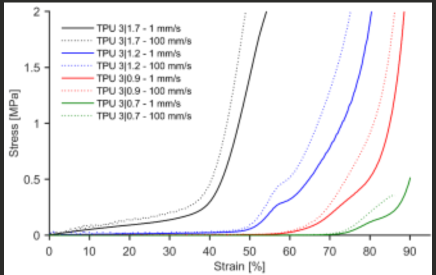
Lattice 1



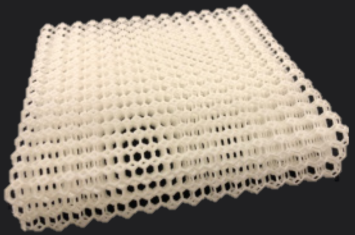


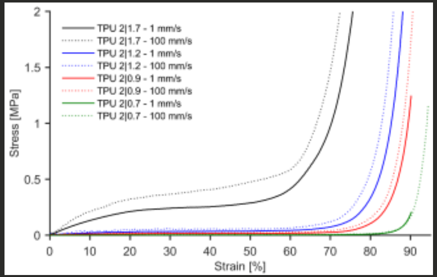
Lattice 3



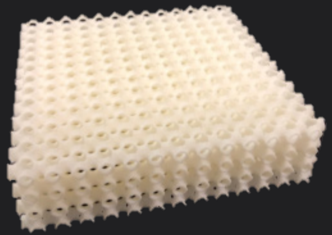


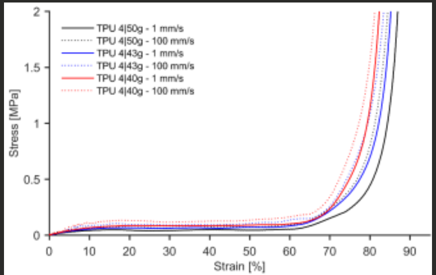
Lattice 2



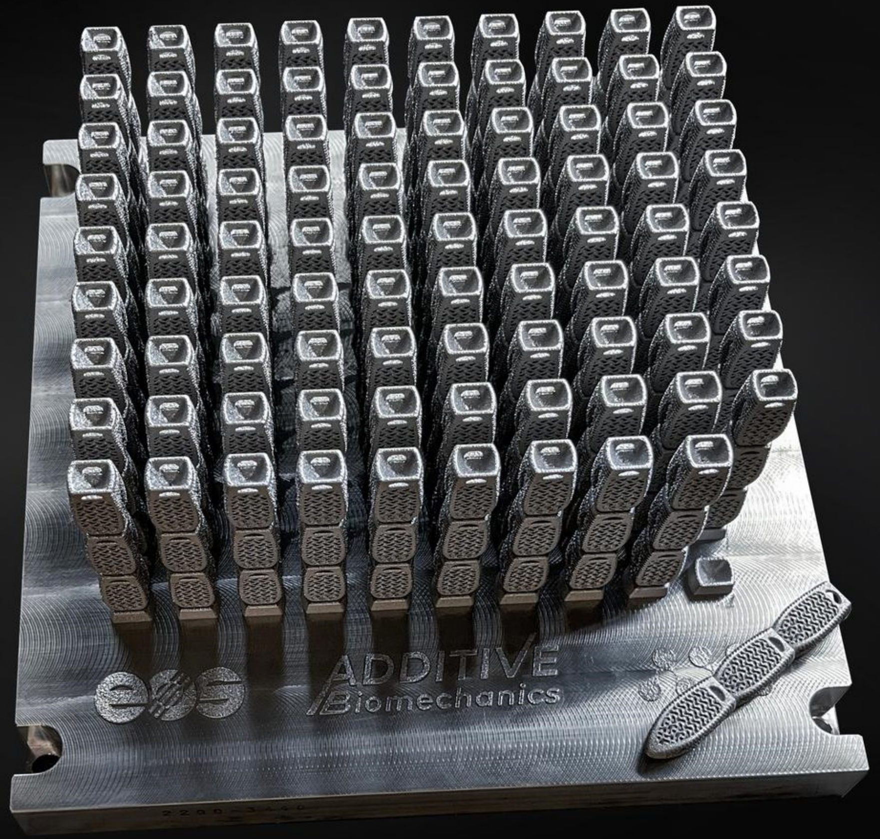


Lattice 4



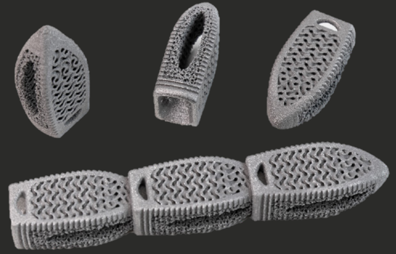


Wolverhampton – Meta Materials: Davy Orye, EOS



Stacked PLIF Cages

Printed with EOS M 290 using
EOS Titanium 64 Grade 23 and 40µm process



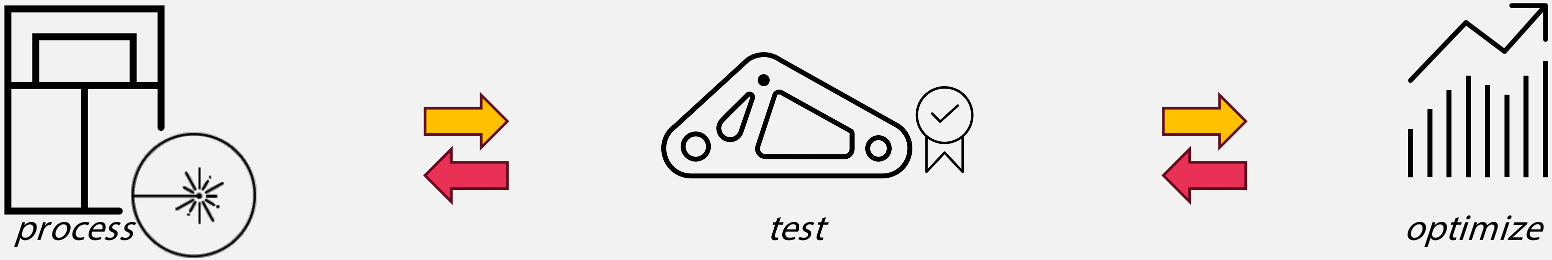
- Support-free stacked PLIF cages
- High fatigue properties without HIP
- 595 MPa fatigue strength for 10 Million cycles
- Voronoi and Gyroid lattice integrated
- 540 PLIF cages per job
- Build time 84 hours or 9,3 mins per cage
- Built on an EOS M 290

Wolverhampton – Meta Materials: Davy Orye, EOS

ADDITIVE Biomechanics

Mechanical properties change through process parameters

EOS SMART Parameter - **invert** your workflow

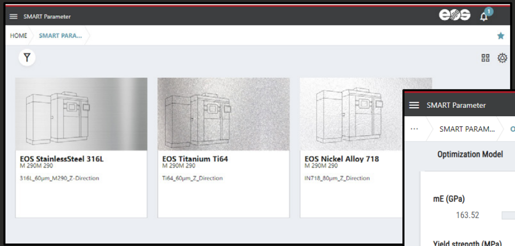


(1) **Specify material properties** to achieve

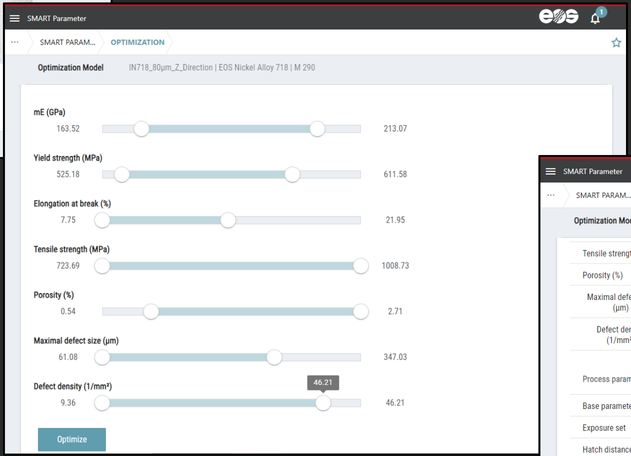
(2) Get **optimized parameters** for highest build rates

(3) **Increase productivity** during build process

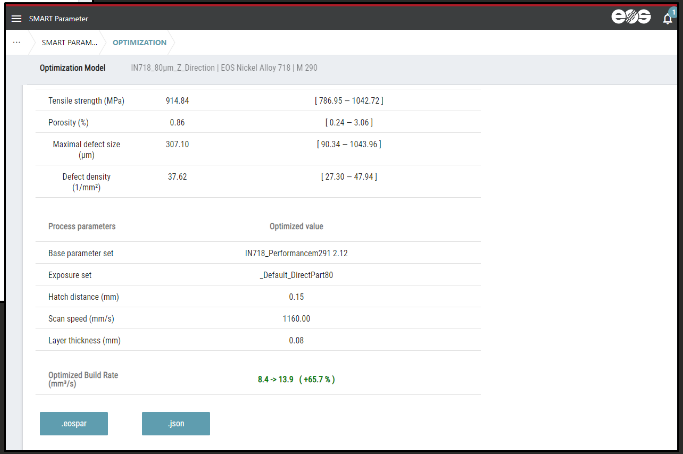
EOS SMART Parameter - easy to use **MVP**



Select your machine / material configuration



Select quality constraints

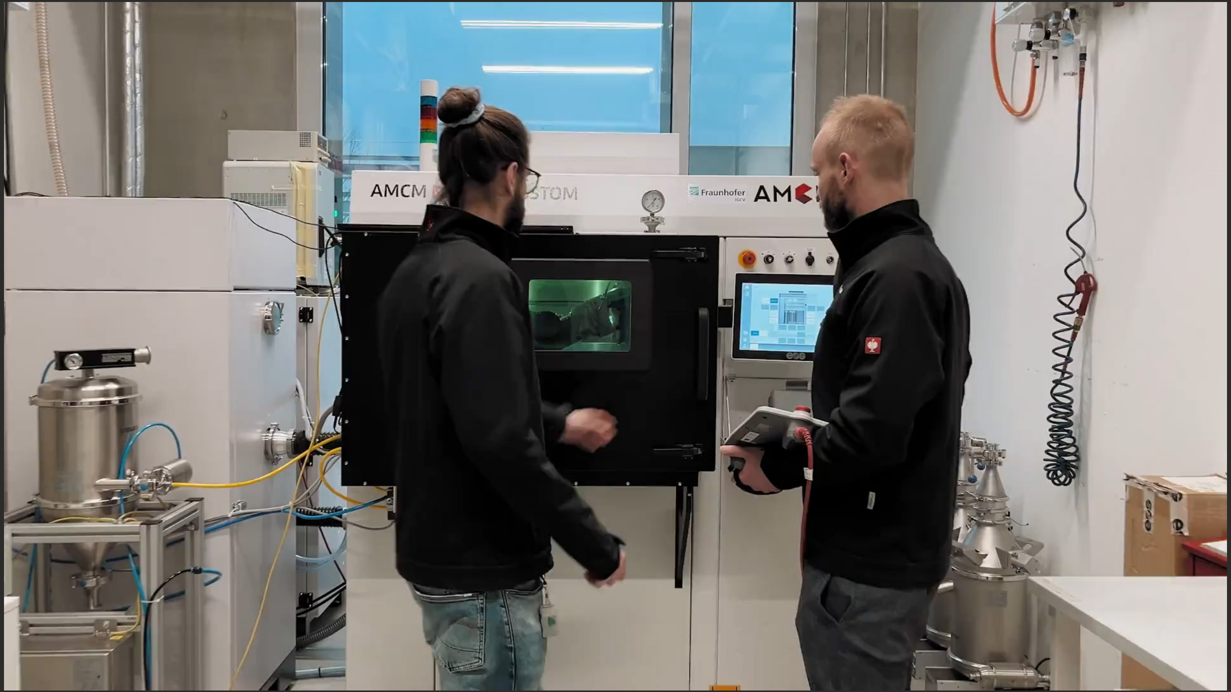


View achieved quality criteria incl. confidence
Get optimized build parameters

Wolverhampton – Meta Materials: Davy Orye, EOS

Multi Material printing

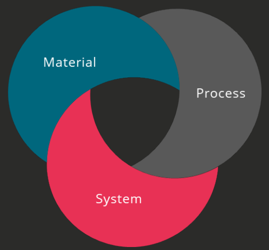
Fidentis (Robotic arm)

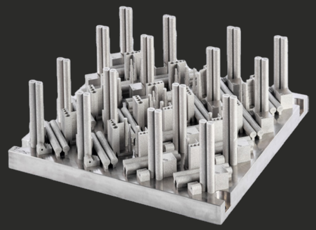


FIDENTIS | Automated production of top quality dentures

Additive Minds

Proven Qualification Strategy for Serial Production





ADDITIVEMINDS®

Machine Capability Study
effort, time and cost can be reduced with Additive Minds support for

FAT → IQ → OQ → PQ → Qualified Production

Factory Acceptance Test

Installation Qualification

Operational Qualification

Performance Qualification

Performed by: EOS

Performed by: Customer
Supported by: EOS Additive Minds

Fastest time to market

Minimize the risk

Regulatory support

Thank you!

Davy Orye

Head of Additive Minds EMEA, EOS GmbH