AIM3D

Approach for Mechanical Isotropic Material Extrusion Printing

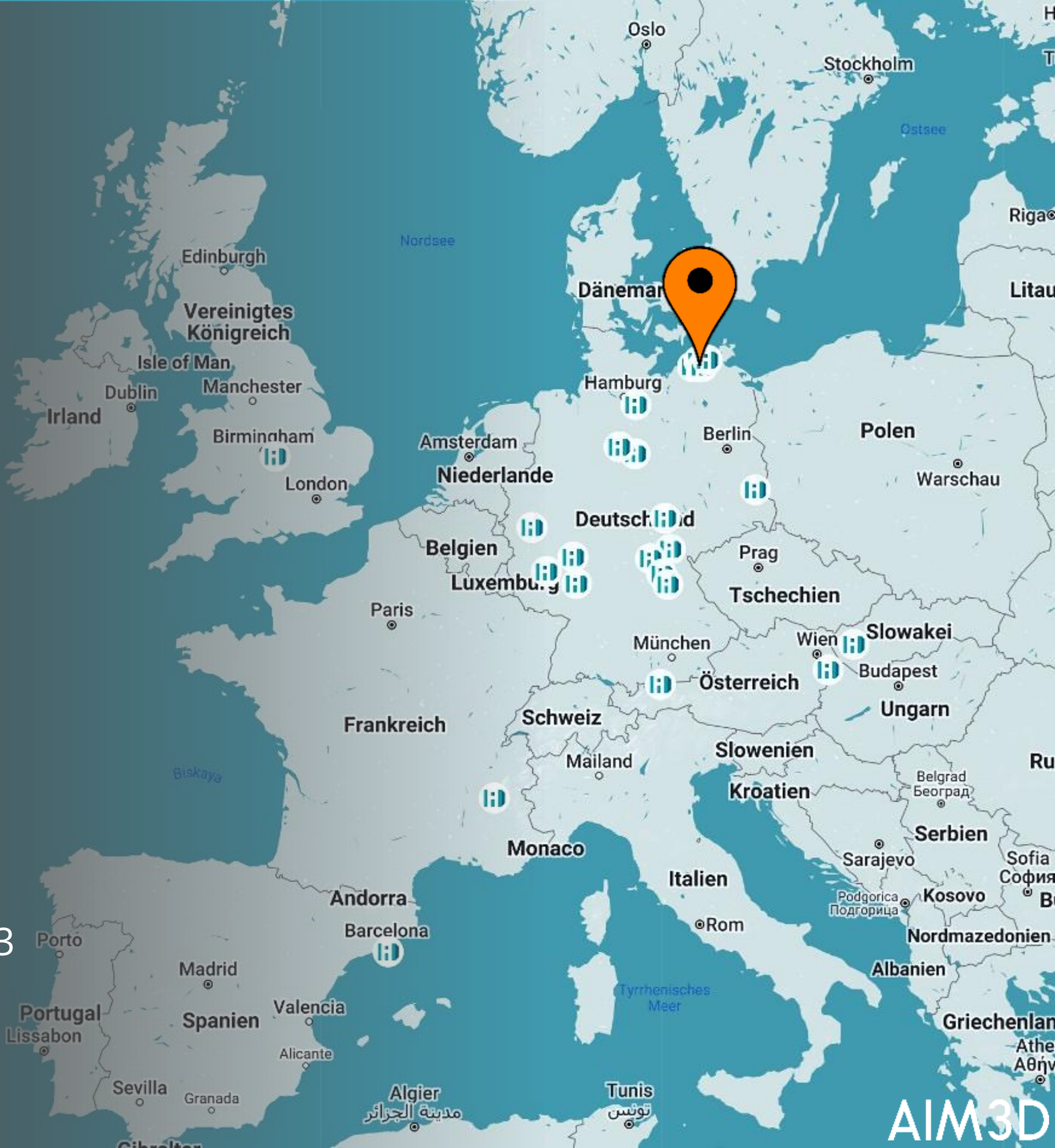
Verena Witt – verena.witt@aim3d.de

Introduction – Verena Witt

2020 B. Sc. in Biomedical Engineering

2023 M. Sc. in Mechanical Engineering

- Joined New AIM3D as a process engineer in 2023
- Develops and optimizes the Voxelfill method



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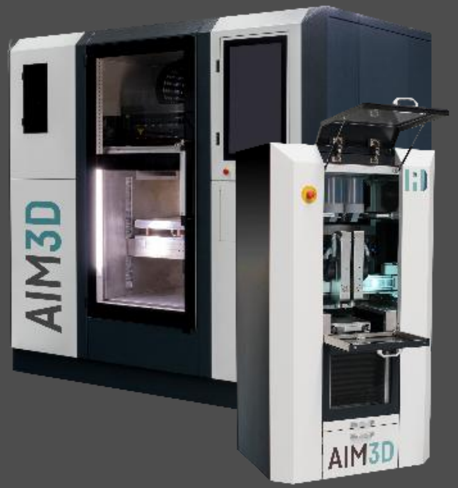
Technology: CEM-process – All in one

Standard injection molding pellets



Industrial 3D printing

Software and Process Optimization

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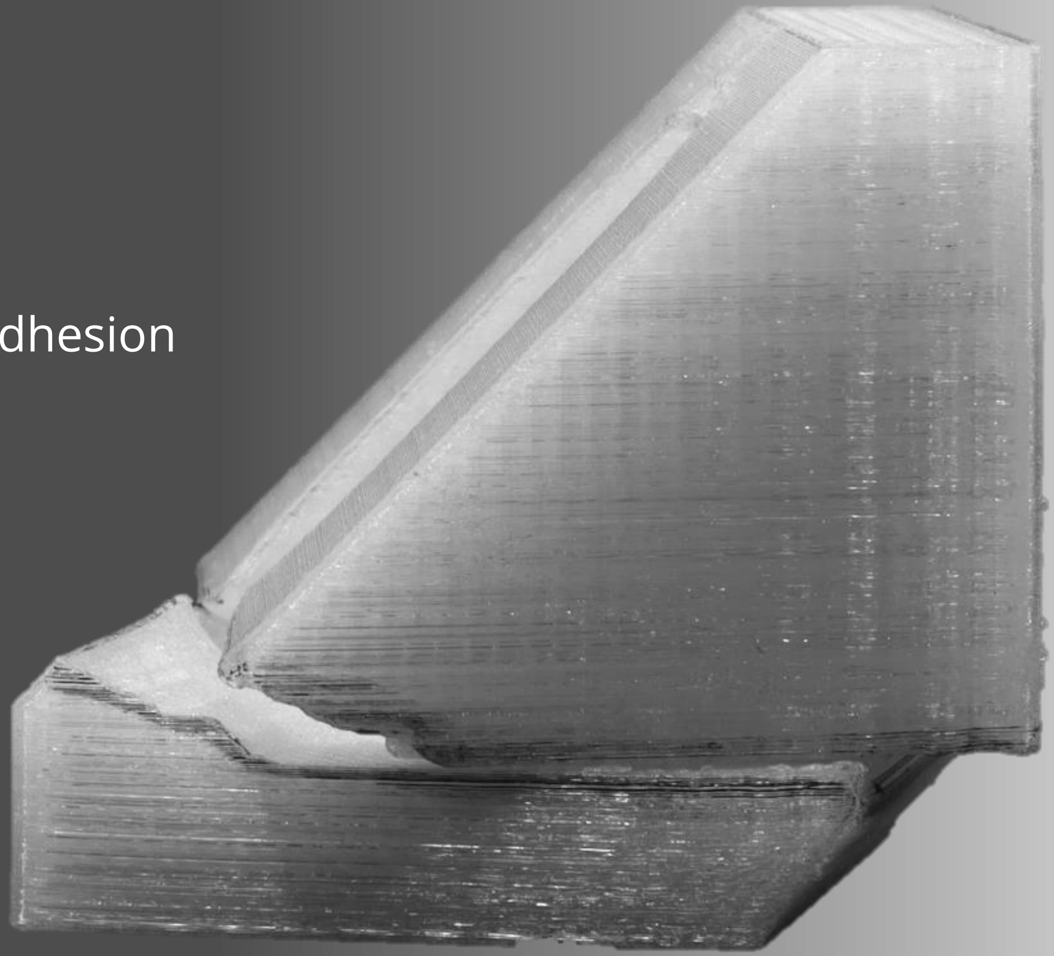
The Problem of Anisotropy in Additive Manufacturing

Extrusion based AM today

- Loss of strength in printing direction
- Part breaks along the layers due to weak adhesion
- Technology often limited to prototypes

→ Hardware optimization is limited

→ Software developement



Printing direction

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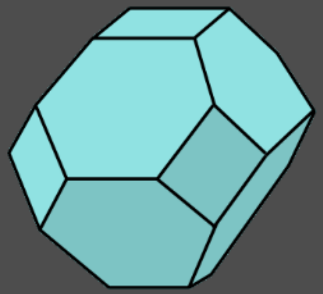
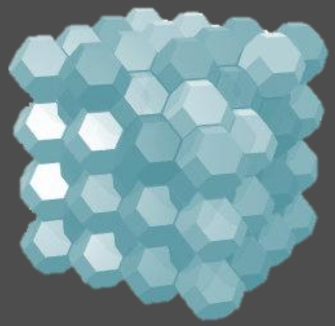
Voxelfill

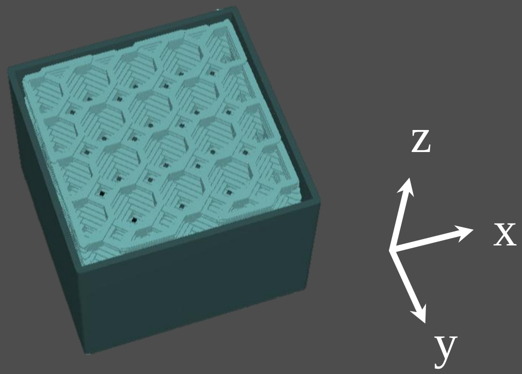
- Combination of material extrusion printing and injection moulding to get isotropic behavior



Voxel geometry



Room filling orientation



Implementation in a slicing software

Increasing the Z-strength of polymer parts

mastering the anisotropy of 3D printed parts

up to 3 times faster print time for solid objects

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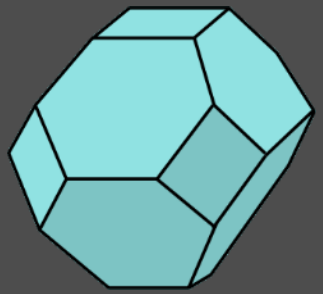
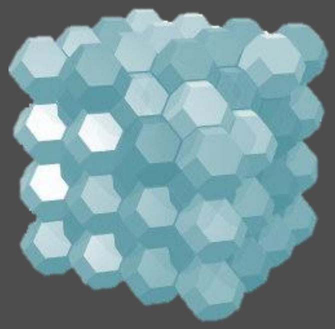
Voxelfill

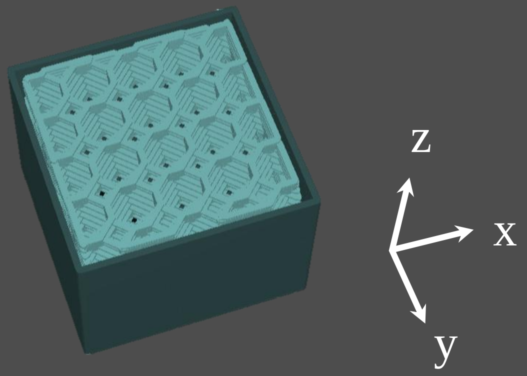
- Combination of material extrusion printing and injection moulding to get isotropic behavior



Voxel geometry



Room filling orientation

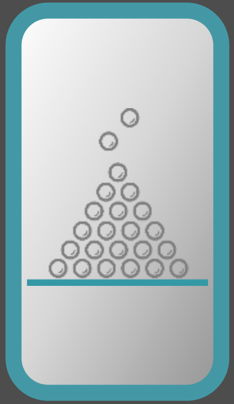


Implementation in a slicing software

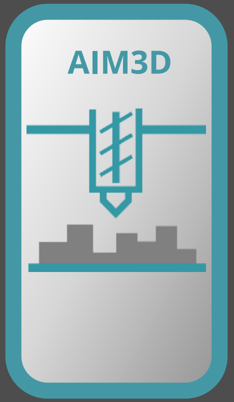
proof of concept needed

Research Overview

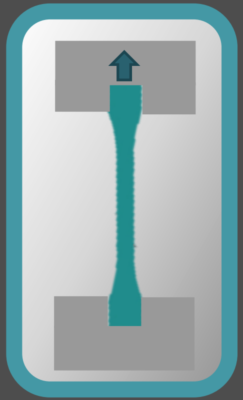
Step 1: Choose material and test method



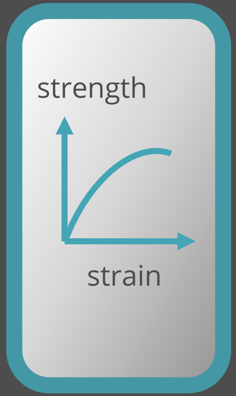
Step 2: Fabricate test samples



Step 3: Characterize samples



Step 4: Discuss anisotropic behavior



Material and Methods: Choose Material and Test Method

Material

- PETG with 30% glassfiber from Polymaker (PETG-1013)
  - Printed conventionally layer by layer
  - Printed with Voxelfill

Test Method

- Density measurements (Archimedes)
- Tensile strength tests (ISO 527)
  - x - direction
  - z - direction
- Confocal microscopy

Parameter	Testing method	Value
Density [g/cm³ at 21.5 °C]	ASTM D792	1.39
Glass transition temperature [°C]	DSC, 10 ° C/min	81

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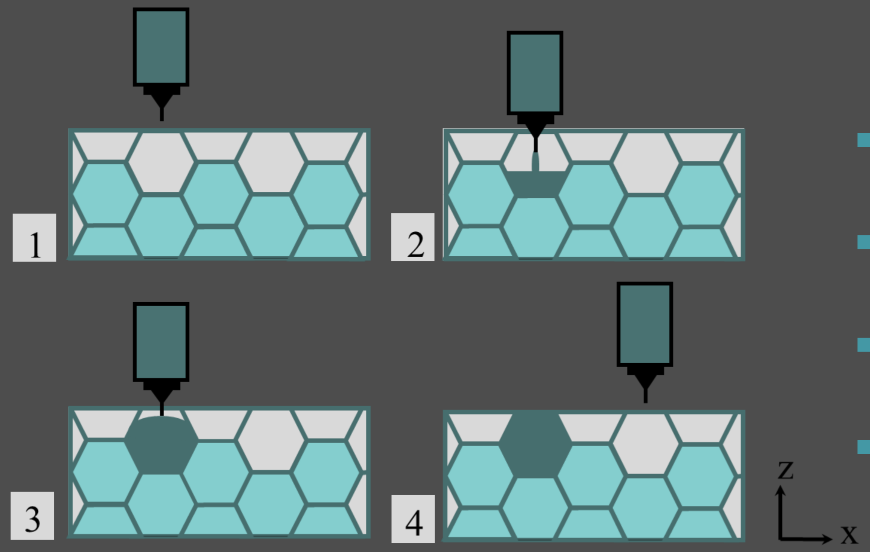
Material and Methods: Fabricate Test Samples

- Printing of samples was done on ExAM255 machine from NEW AIM3D
- Parameters for printing conventionally were searched
- Filling of the voxels was optimized

Parameter	Value	Unit
Bed temperature	70	°C
Feed zone temperature	45	°C
Nozzle temperature	270	°C
Nozzle diameter	0.5	mm
Layer height	0.1	mm
Line width	0.6	mm
Printing speed	80	mm/s
Extrusion flow factor perimeter	98	%
Extrusion flow factor ± 45°	98	%
Extrusion flow factor Voxelfill	120	%
Retraction	3	mm
Retraction speed	25	mm/s



- Temperature
- Material amount
- Speed
- Waiting times

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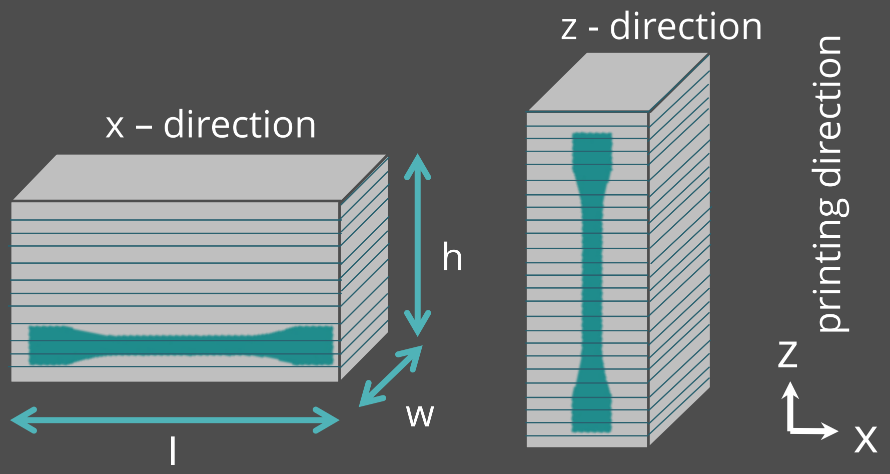
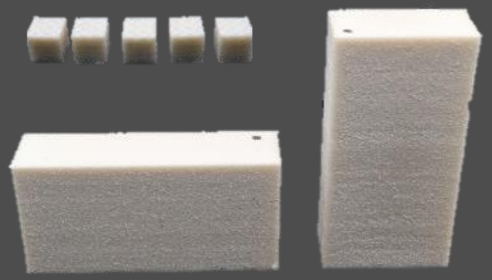
Material and Methods: Fabricate Test Samples

- Four test groups were printed
  1) Conventional printing in x-direction
  2) Conventional printing in z-direction
  3) Voxelfill in x-direciton
  4) Voxelfill in z-direction



- 10x10x10 mm cubes for density measurements
- Tensile samples were milled out of printed blocks



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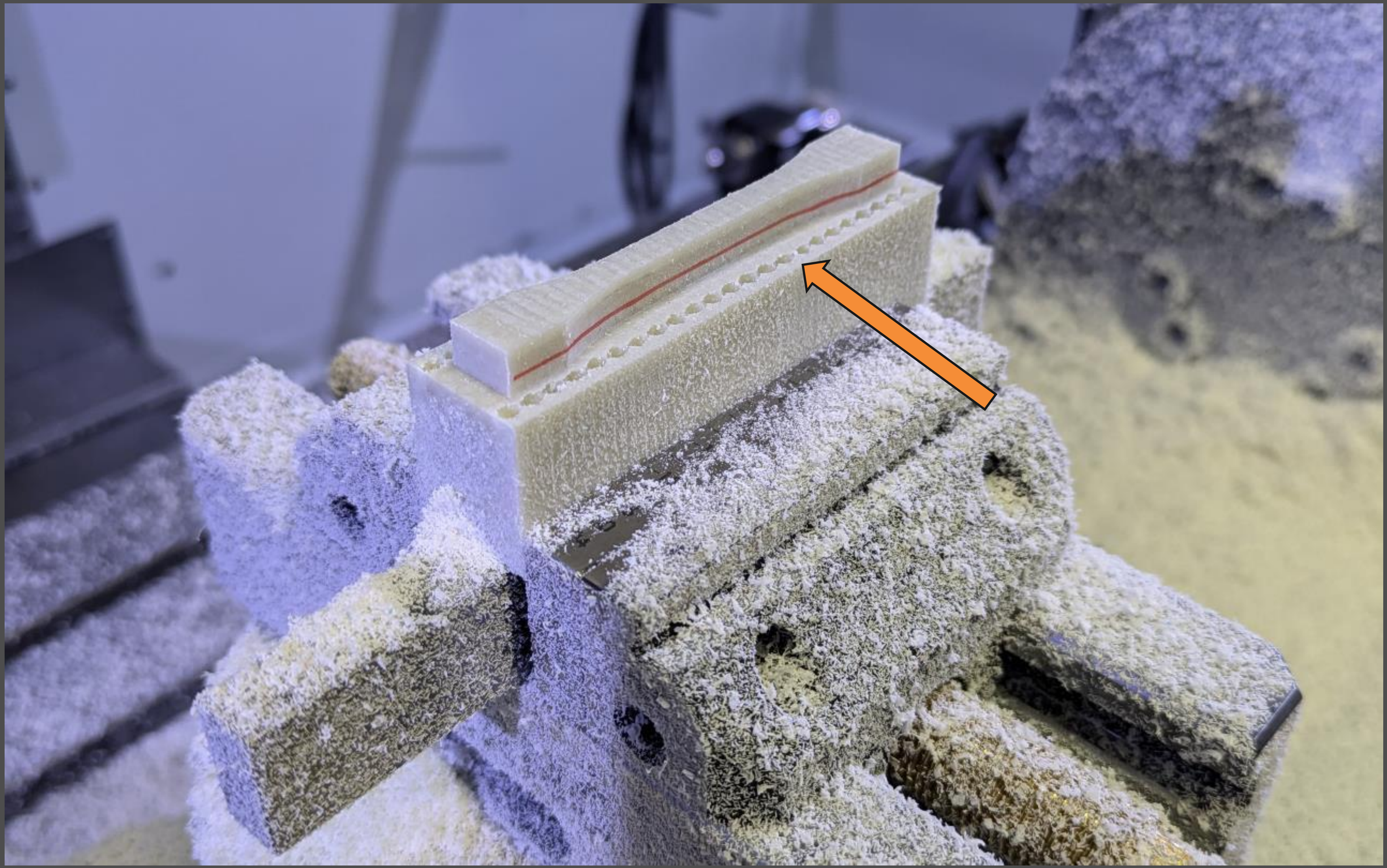

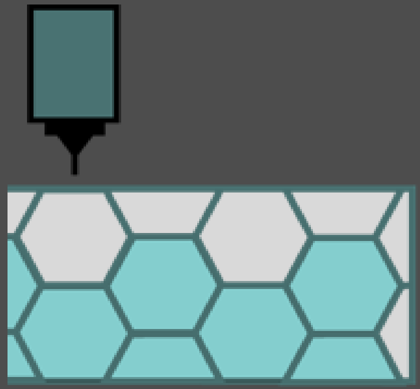

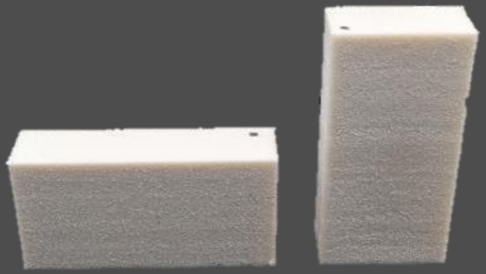

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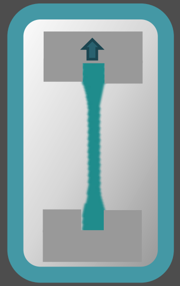
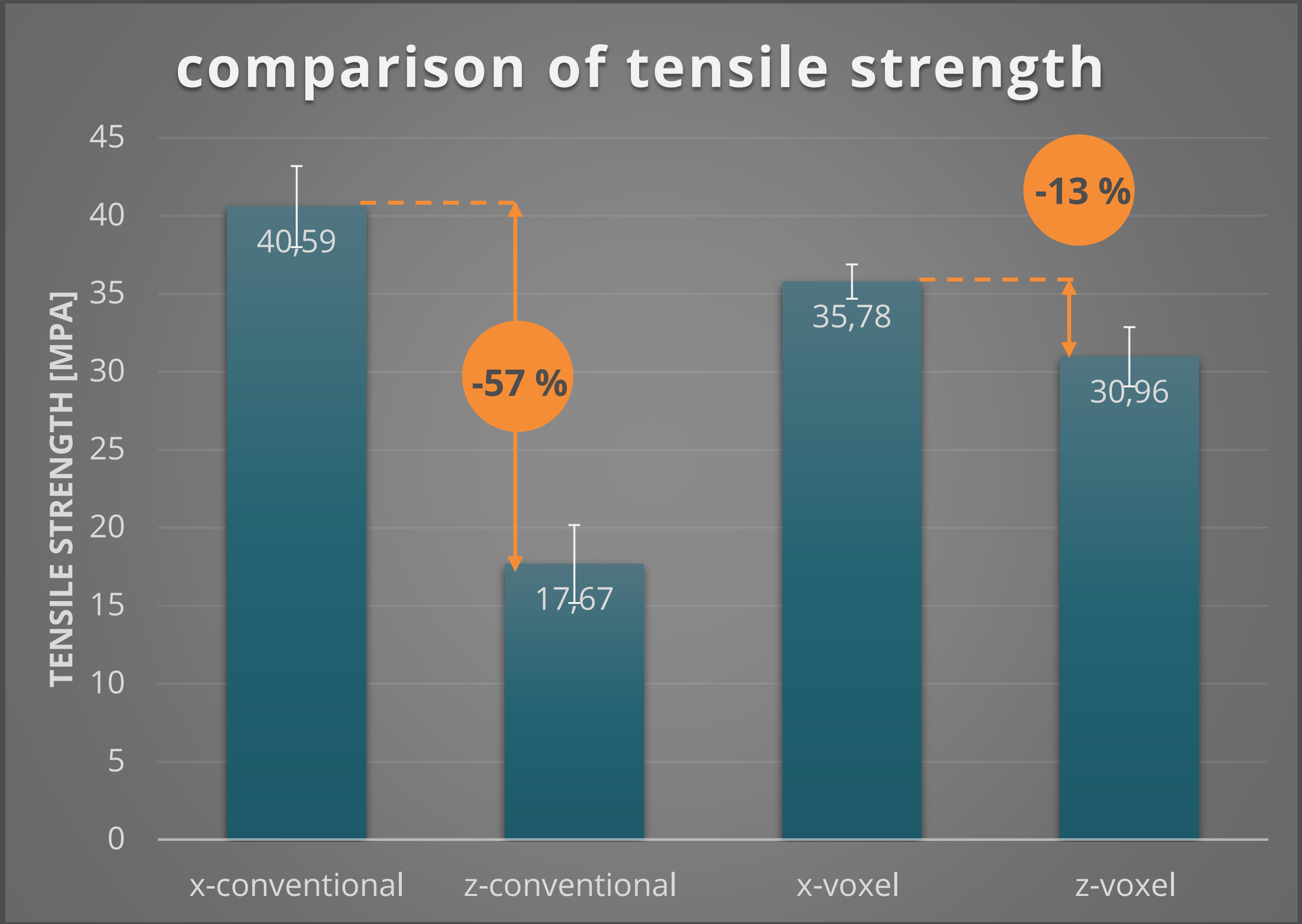
Results : Tensile Strength Tests





Density of Voxelfill samples was 94%

Anisotropy decreased from 57% to 13%

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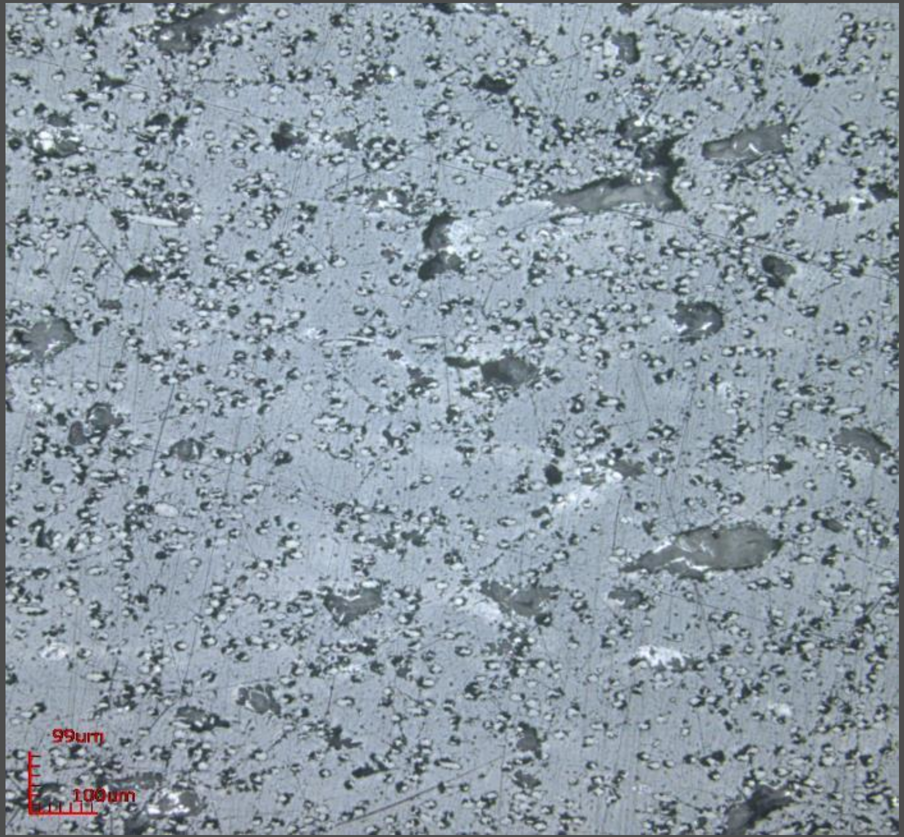
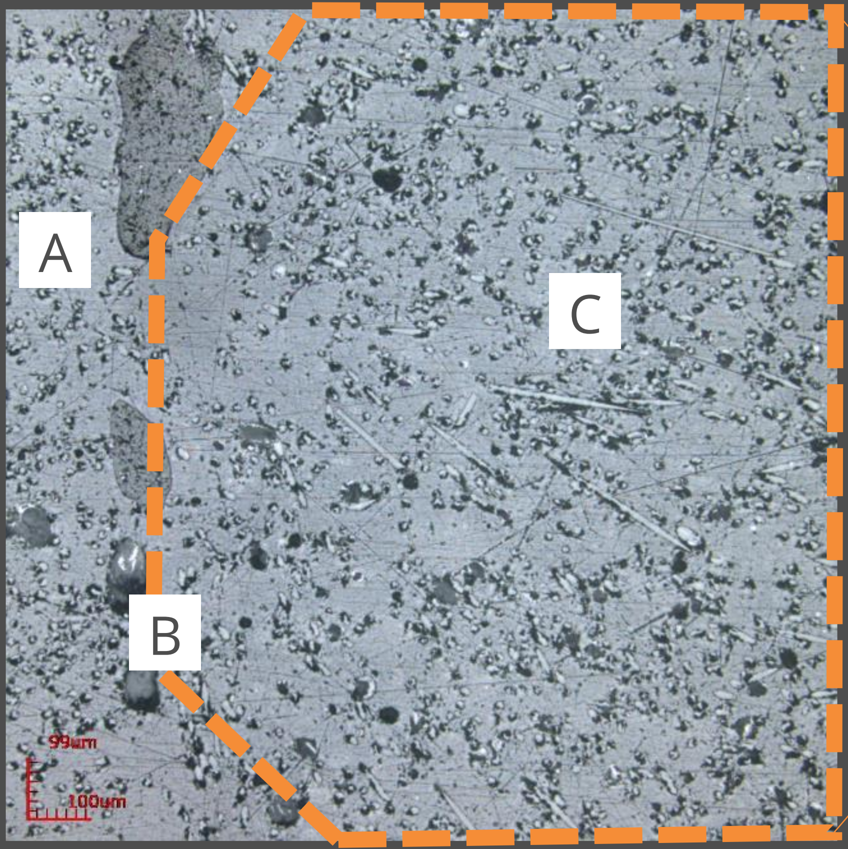
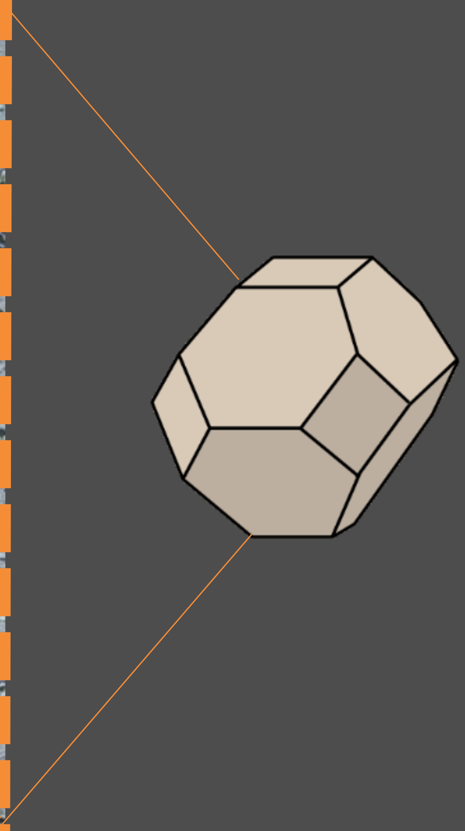
Results: Fiber Distribution in z-Direction



Z





Conventional

Voxelfill

A – base structure
B – boundary area
C – Voxel area

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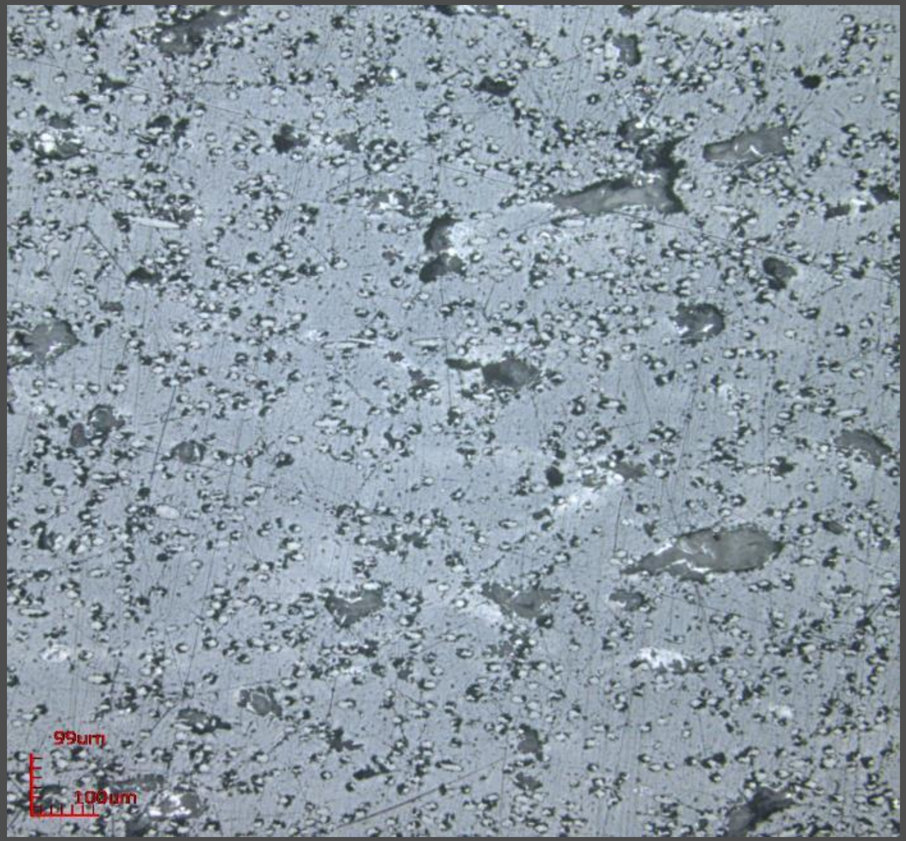

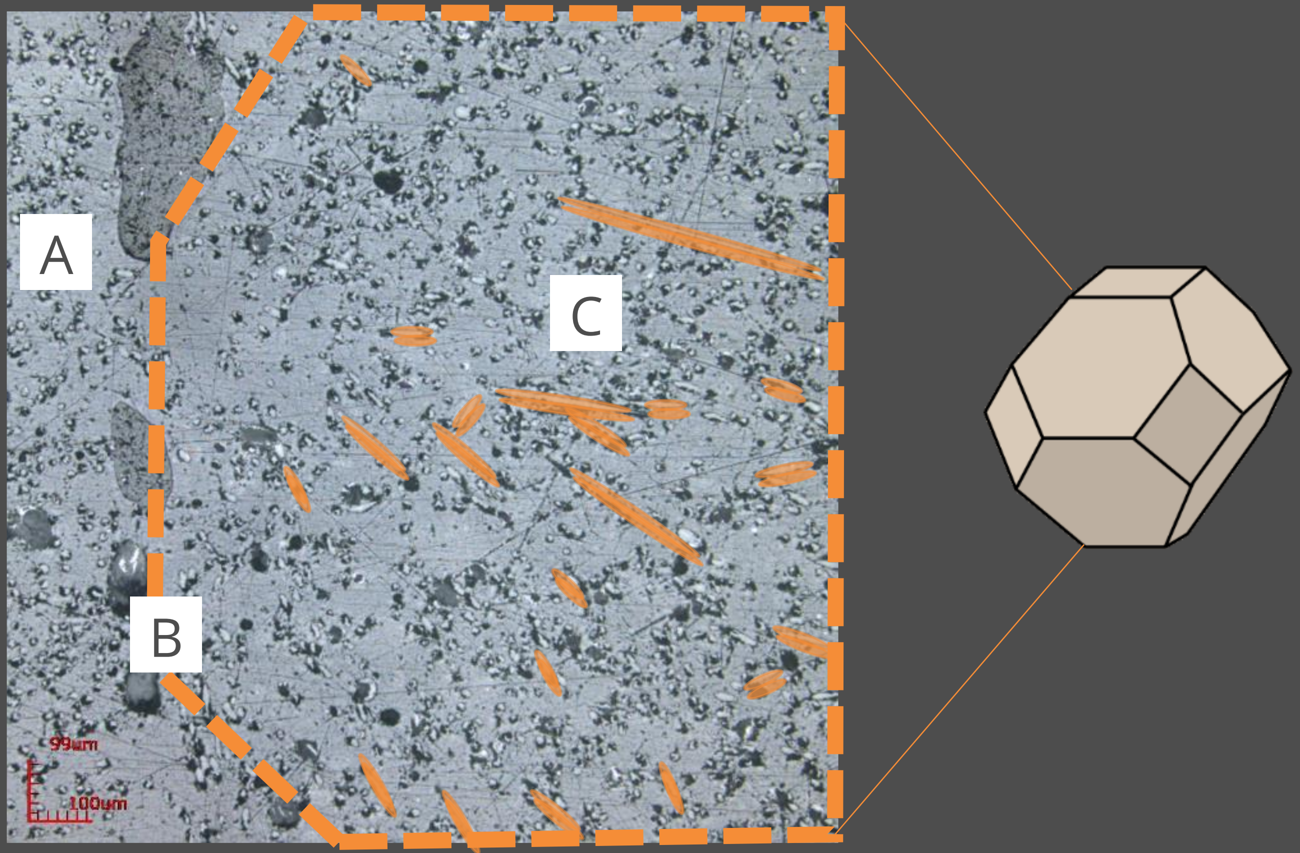

Conventional

Voxelfill

A – base structure
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Step 4: Discuss Results

- Voxelfill samples showed lower density of 94 %
- Microscopy showed fibers distributed in z-plane
- Anisotropy in tensile strength was reduced to 13 %
- Maximum tensile strength decreased by 12 %

→ What about other research?

Material	Anisotropy [%]	Strategy	Anisotropy [%] after strategy	Decrease in x-strength [%]	REF
PLA	52.00	-	-	-	[32]
ABS	65.50	-	-	-	[33]
PLA	32.90	z-pinning	9.08	59.89	[8]
PLA-CF	32.72	z-pinning	29.32	65.18	[8]
PETG-GF	56.71	Voxelfill	13.47	11.86	

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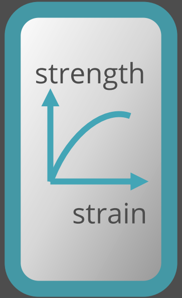

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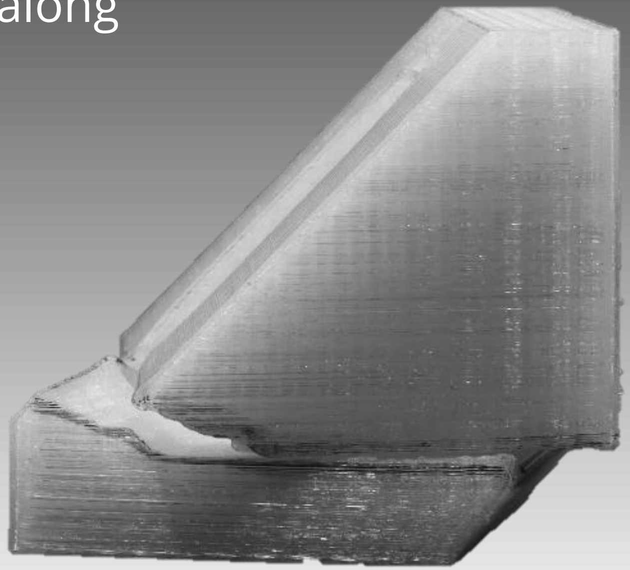
The Problem of Additive Manufacturing – Solved!

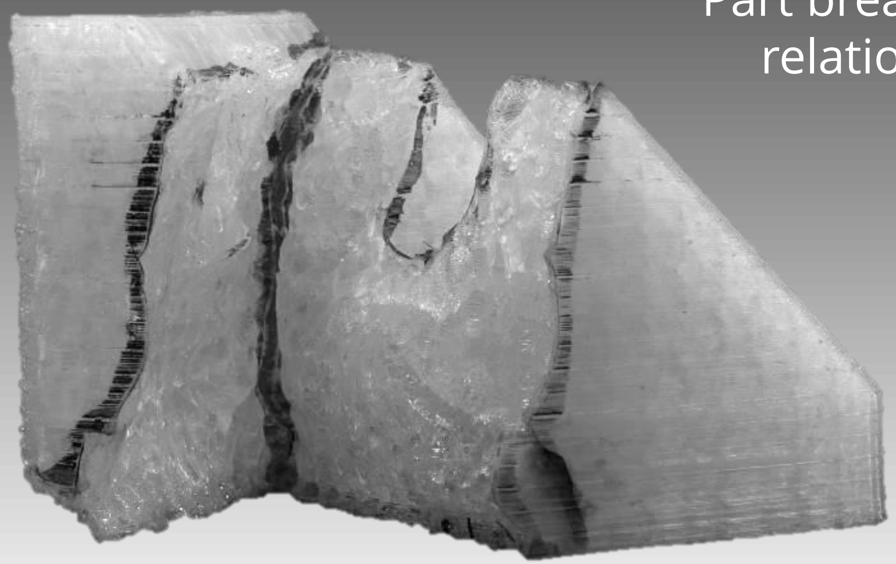
AM today

~40 % strength in printing direction

Part breaks along
the layers



Printing direction



Voxelfill

~85-100 % strength in printing direction

Part breaks with no
relation to layers

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LFM

EUROPÄISCHE UNION

Create it REAL

AIM3D

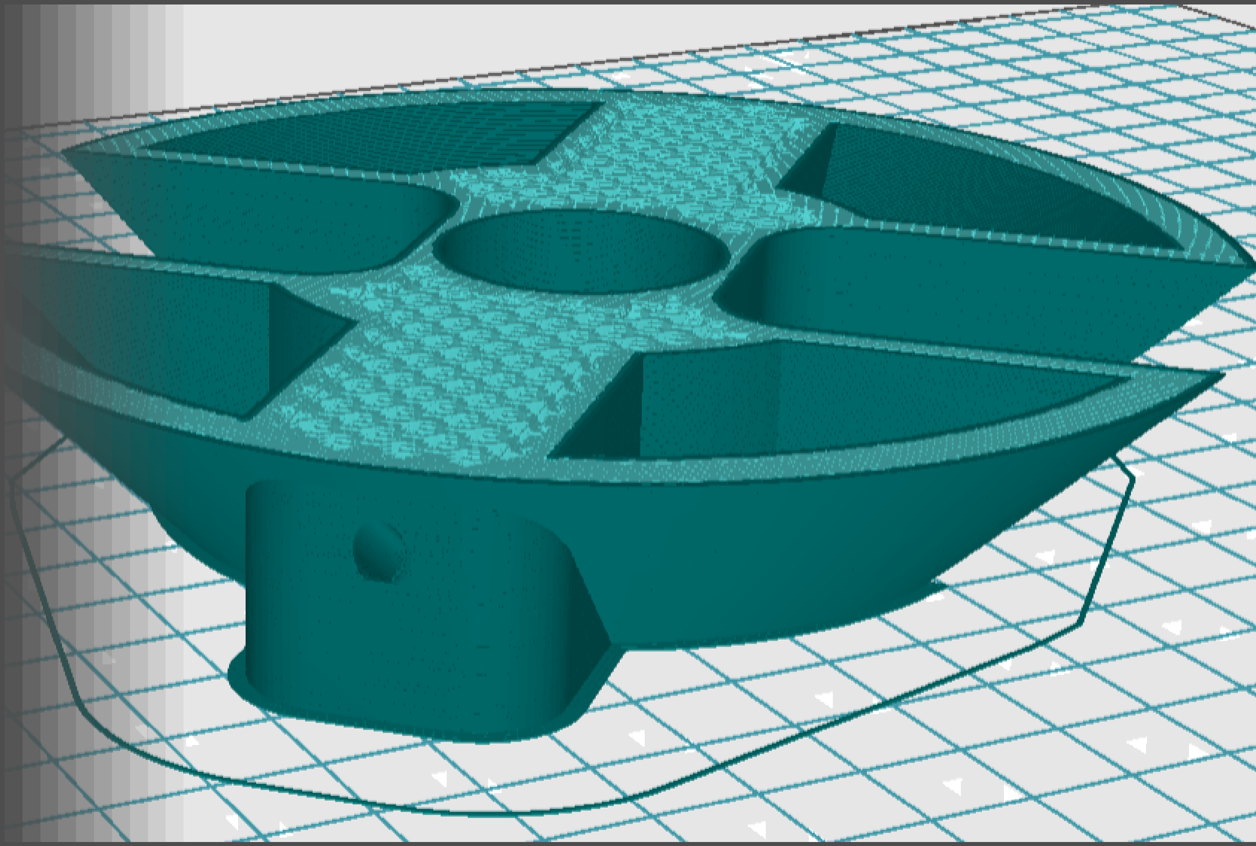
Questions

Verena Witt – verena.witt@aim3d.de

Use Case

Housing for dairy food production

- PLA (food certified)
- previously part failure at drilling holes
- locally printing with Voxelfill enhances strength and prolongs life cycle of the product

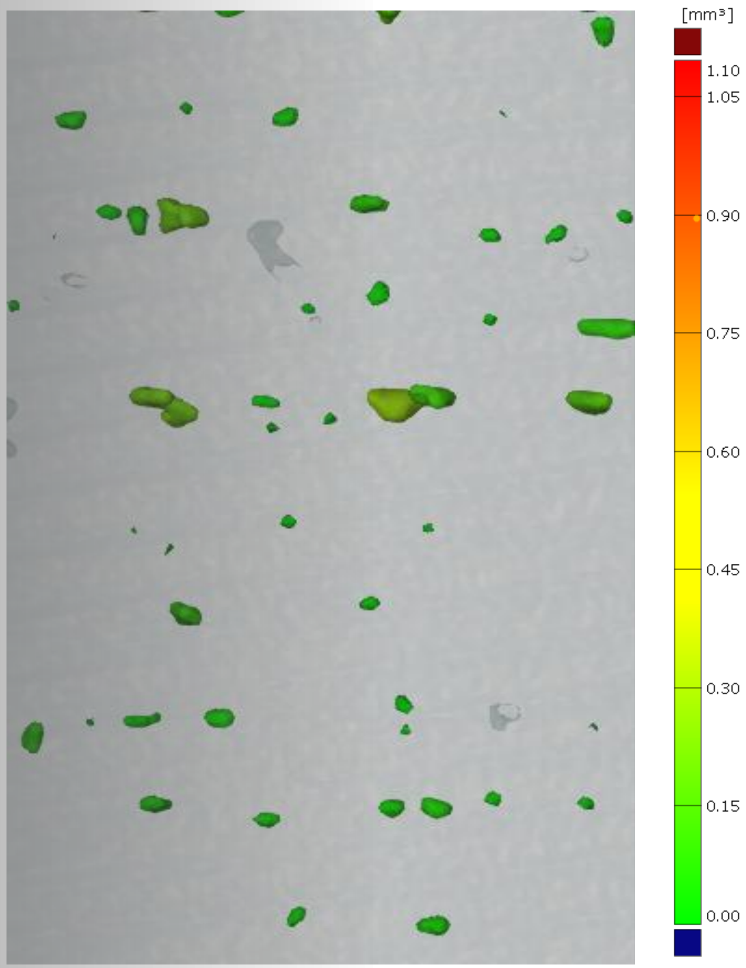


Mastering applications in the field of

- Food production

Outlook and potential

- Despite high tensile strength, the Voxelfill samples still have pores (air pockets) in the range of <0.15 mm^3
- By further optimising the filling density, an even higher tensile strength and thus isotropy is conceivable
- The potential of the process is expanded through the processing of fibre-reinforced materials and multi material strategies



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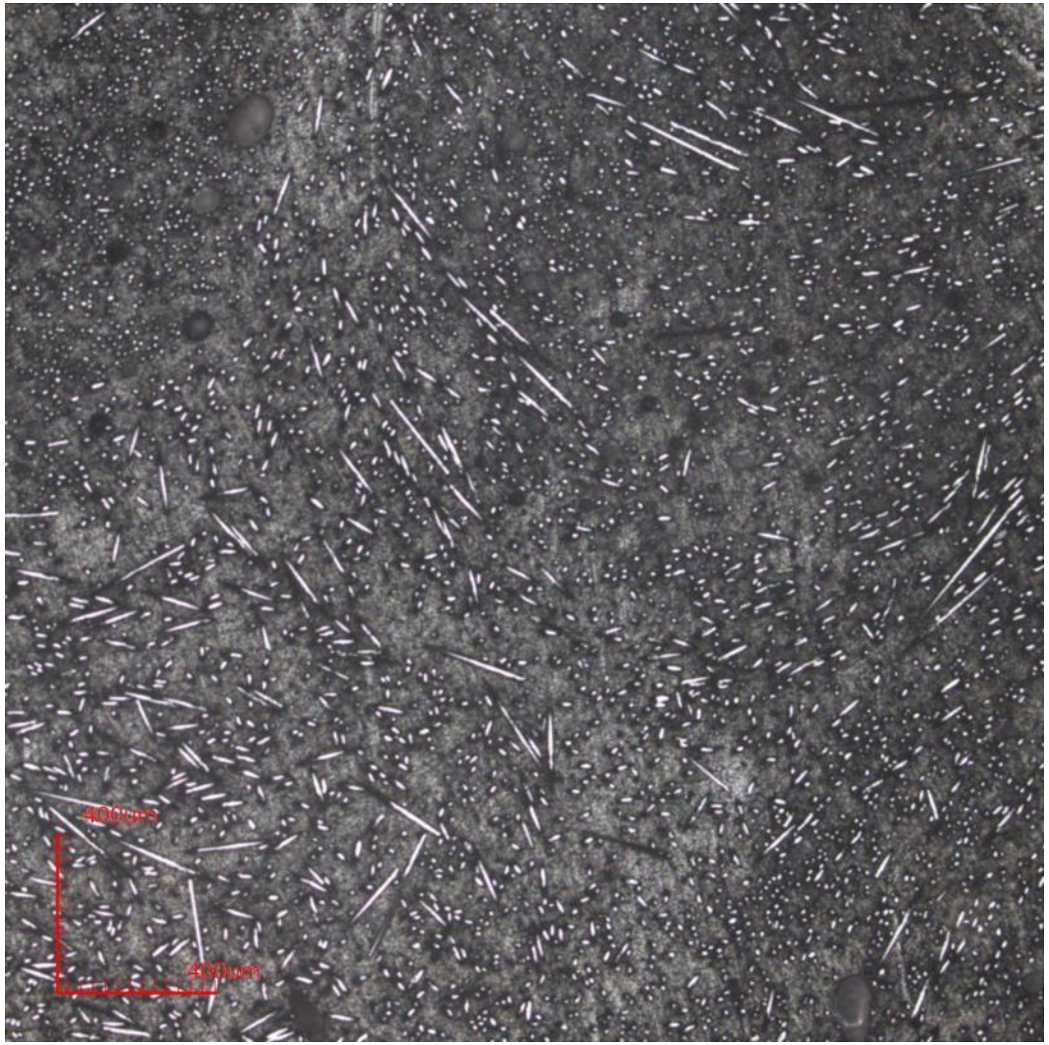
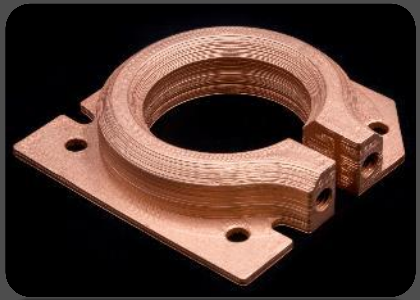
400um
400um


400um
400um

The Widest Material Portfolio in Additive Manufacturing

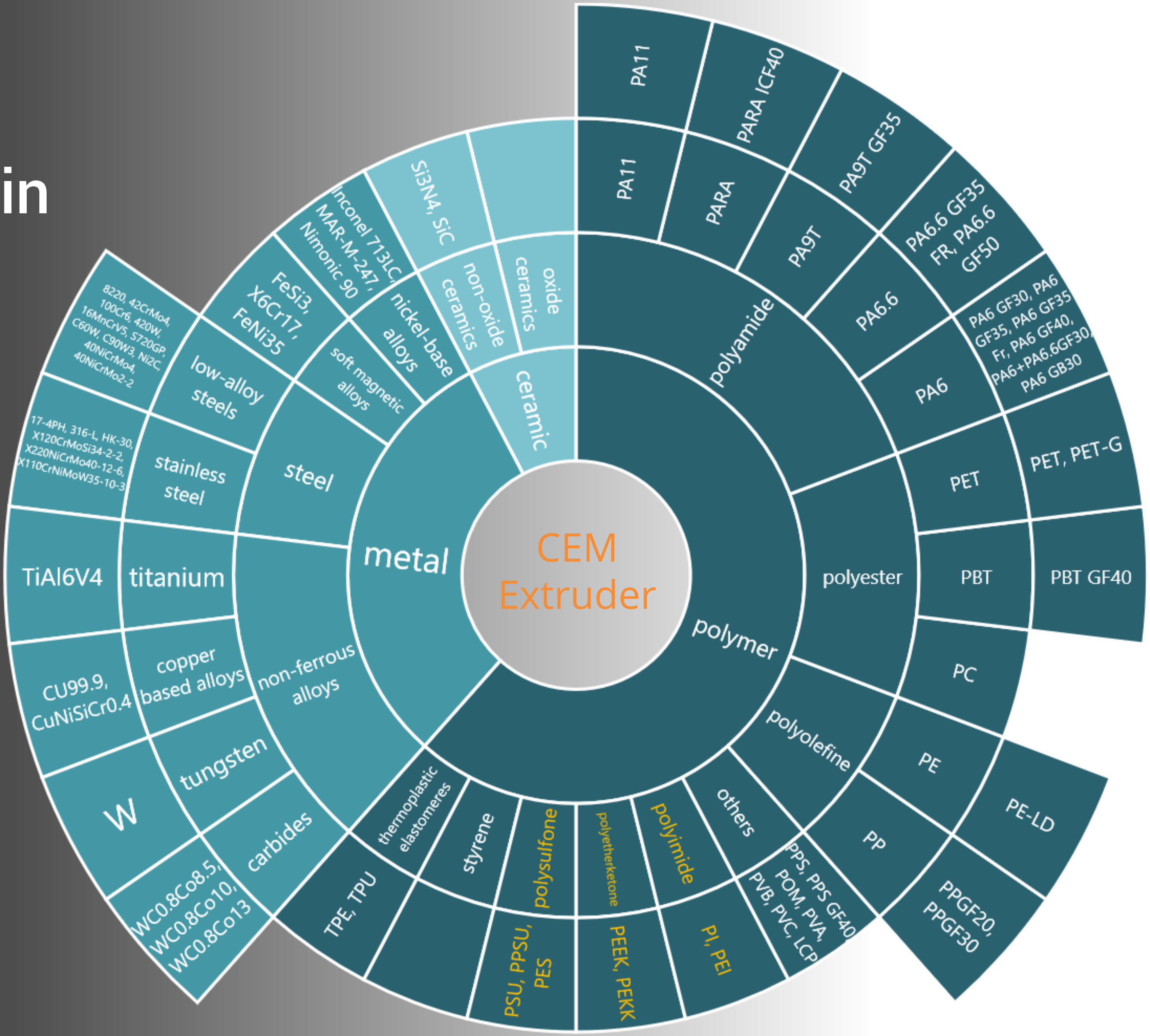


Conductivity

Flexibility

Flame Resistance

Chemical Resistance



* Only on the ExAM510

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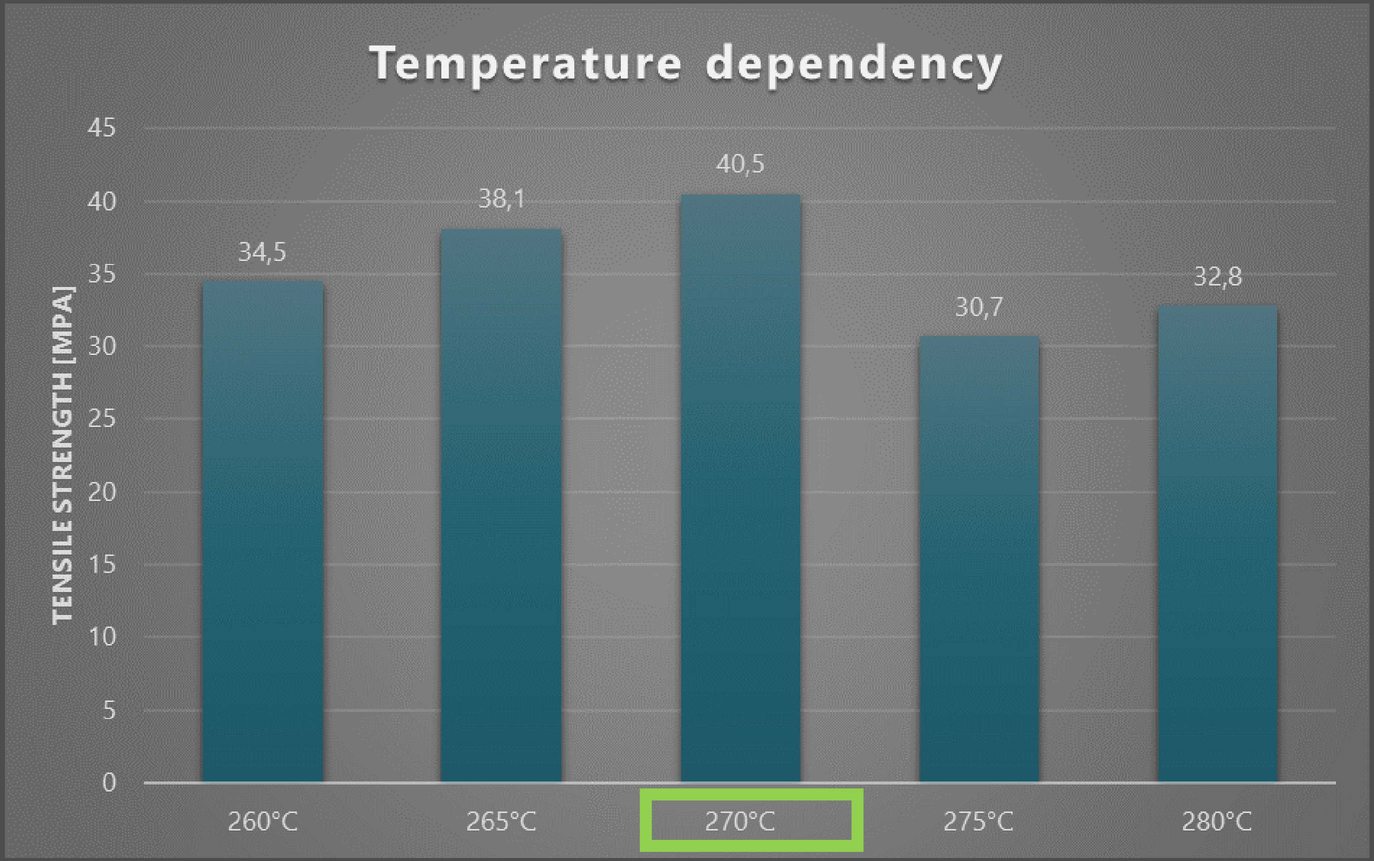
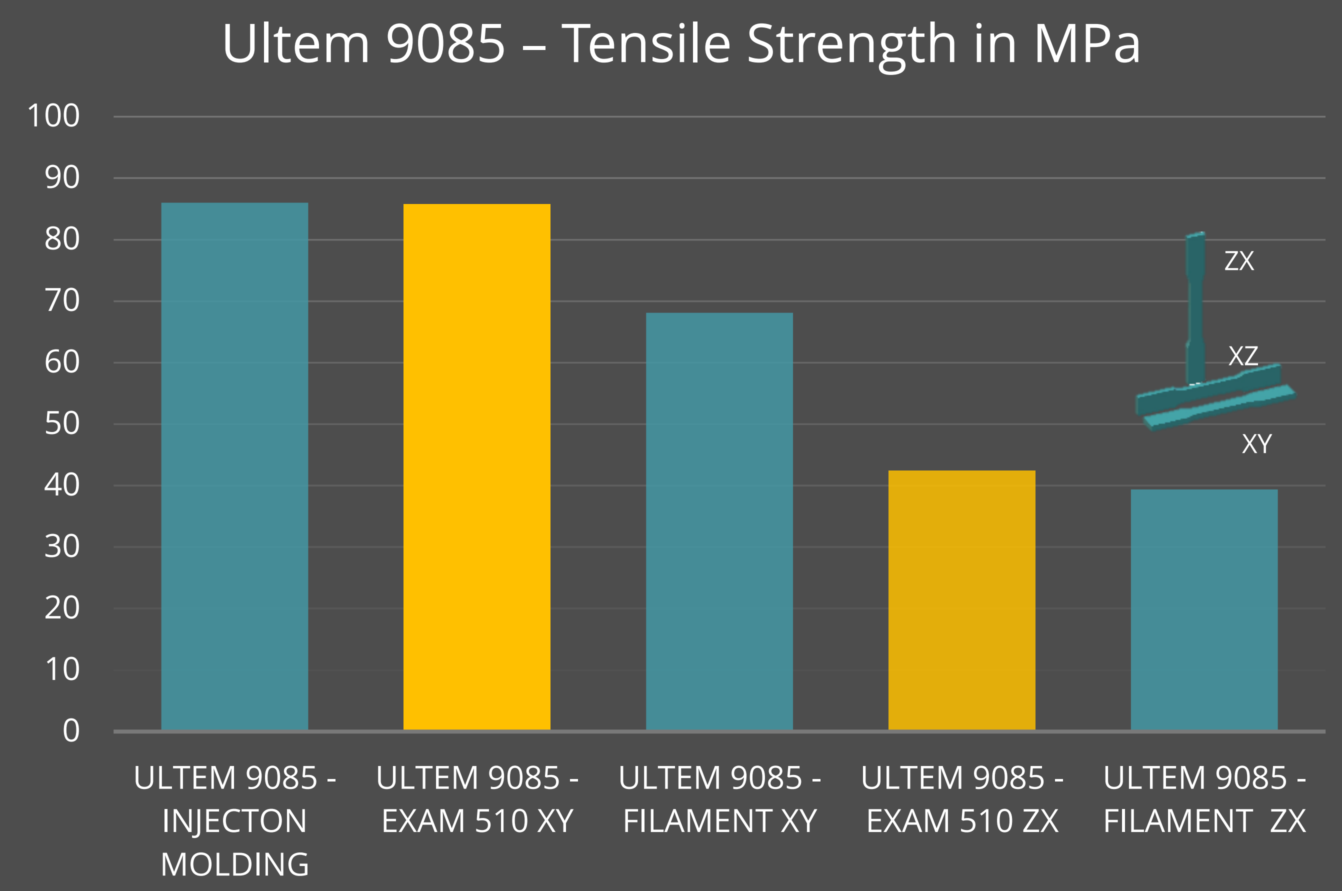
Temperature Analysis



PEI – Versatile Material made Affordable in Pellet Form



* Values without Voxelfill

ExAM 255

- Pellet 3D Printer with versatile use cases

User:

- Metal- and Ceramic Injection Molding Companies
- Research institutes and colleges
- Material compounders and manufacturers

3D Print:	Dual print with two materials
Build Space:	255 x 255 x 255 (mm^3)
Build Rate:	20 - 40 cm^3/h (with 0.4 mm nozzle) (depends on material)
Heated Bed:	Up to 120 °C, removable
Supply:	230V/10A, 5.5 bar press. air

98 T € SP

Go to Market 2019

30 installed machines

AIM3D

ExAM 510

- Industrial pellet 3D Printer for high performance polymers
- User:
  - Aviation suppliers
  - Transportation suppliers
  - Automotive & gen. production

3D Print:	Multi-material with up to three materials
Build Space:	510 x 510 x 400 (mm³), heated up to 200°C
Build Rate:	Up to 250cm³/h (with 0.4 mm nozzle) (depends on material)
Heated Bed:	Up to 200 °C, vacuum table
Supply:	400V/32A, 5.5 bar press. air

350 T € SP

Go to Market 2024

6 installed machines

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