ADDITIVE MANUFACTURING OF STRUCTURAL COMPONENTS WITH IMPROVED THERMAL MANAGEMENT

Tessa ten Cate

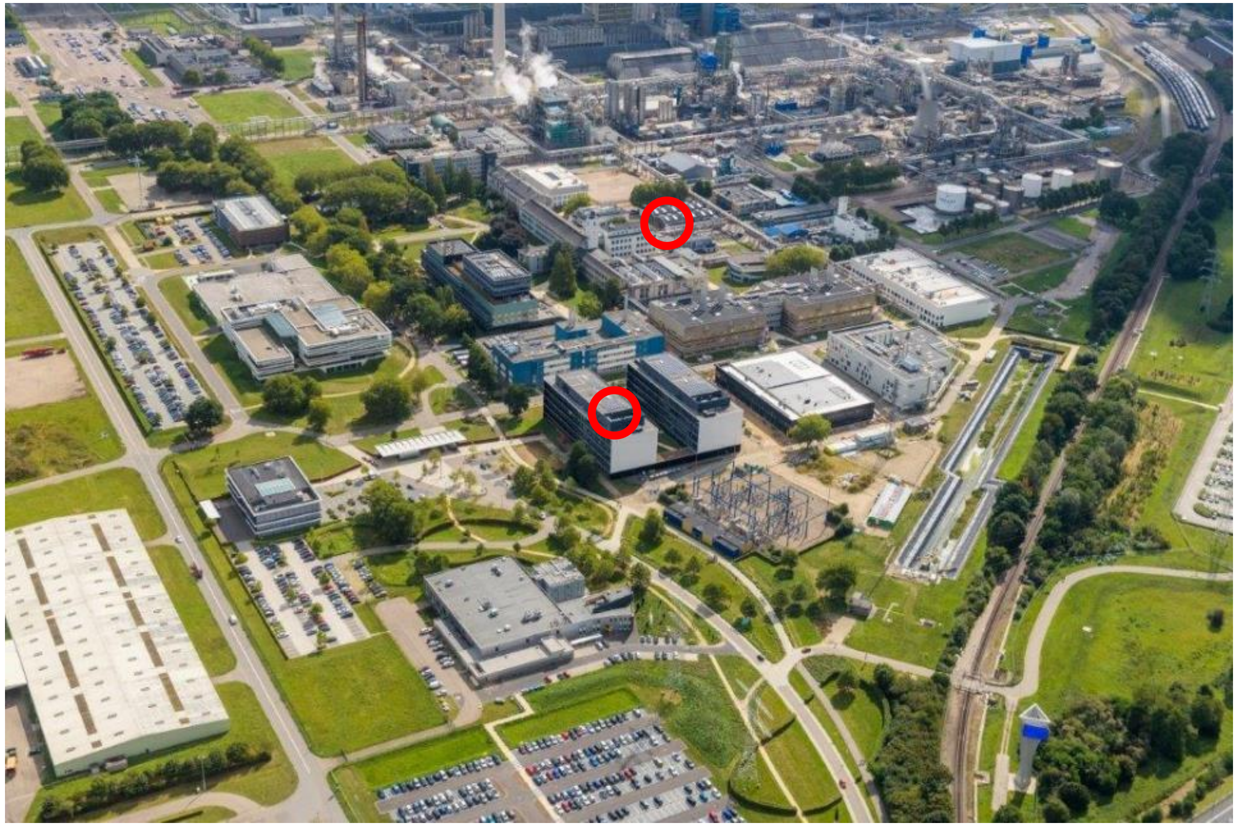
NAG Webinar, October 10, 2024

BRIGHTLANDS MATERIALS CENTER

- Brightlands Materials Center is an independent R&D Center in the field of polymeric materials

- Brightlands Materials Center was established in March 2015 by TNO and the Province of Limburg

- Brightlands Materials Center is located at the Brightlands Chemelot Campus in the south of the Netherlands

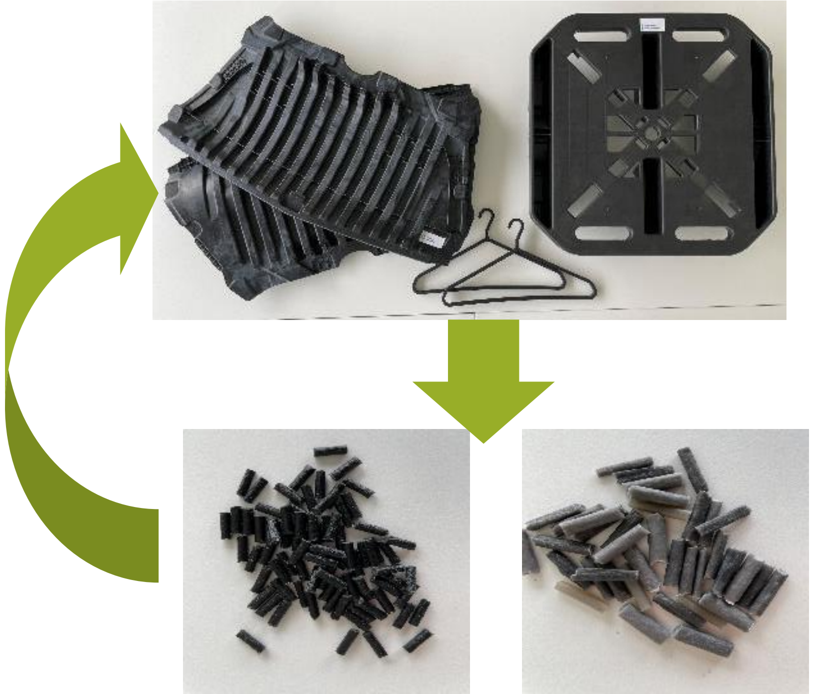


THERMOPLASTIC COMPOSITES FOR SUSTAINABLE MOBILITY

Supporting the mobility sector to accelerate the material and energy transition

TPC Recycling

Recycled fiber reinforced thermoplastics with good mechanical performance



Lightweight Structural CFAM

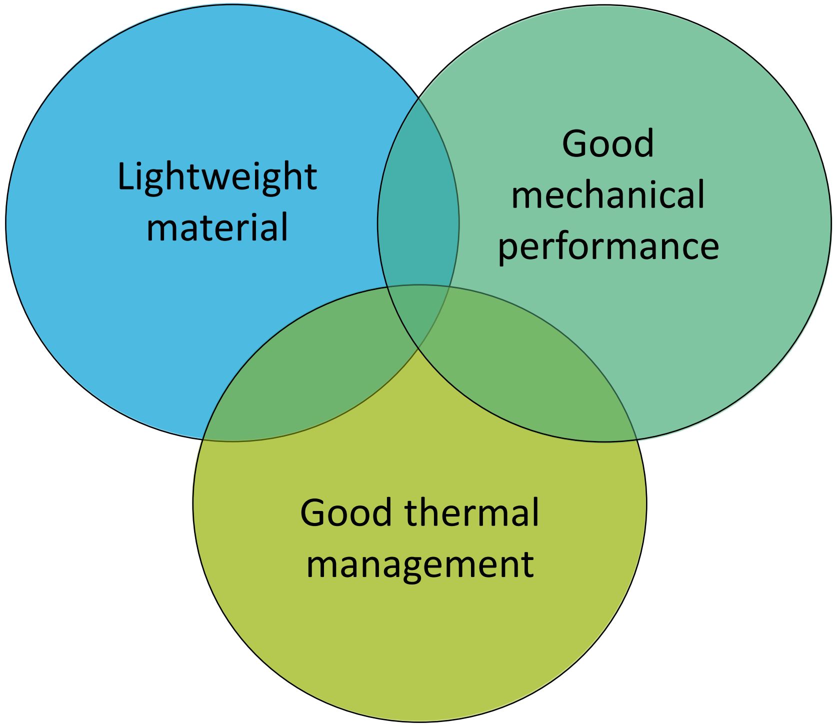
Weight reduction by (1) metal replacement by composites and by (2) shape optimization

LIGHTWEIGHT STRUCTURAL COMPONENTS

EU-project MULTHEM – applications in aeronautics & e-mobility

MULTHEM
Multi Material Additive Manufacturing for Lightweight and Thermal Management
www.multhem.eu

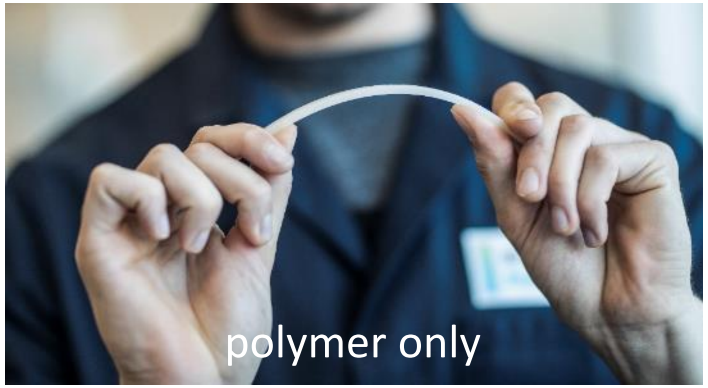
- Lowering carbon emissions in the transport sector by weight reduction
- Additive manufacturing technology of carbon fiber composites to replace structural metal components
- Multi material approach for enhanced thermal conductivity

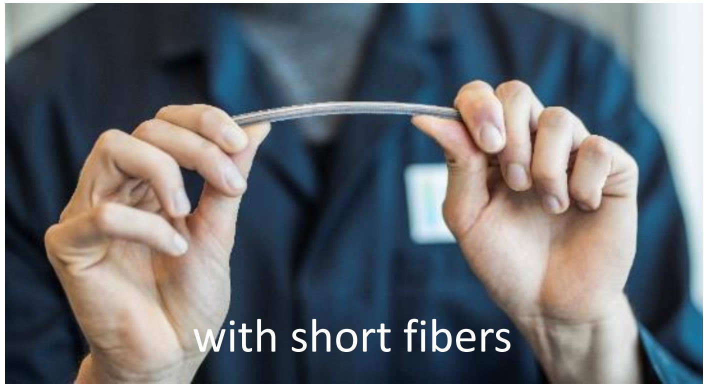


This project has received funding from the European Union's Horizon Europe Research & Innovation programme 2021 -2027 under grant agreement number:101091495

THERMOPLASTIC COMPOSITES

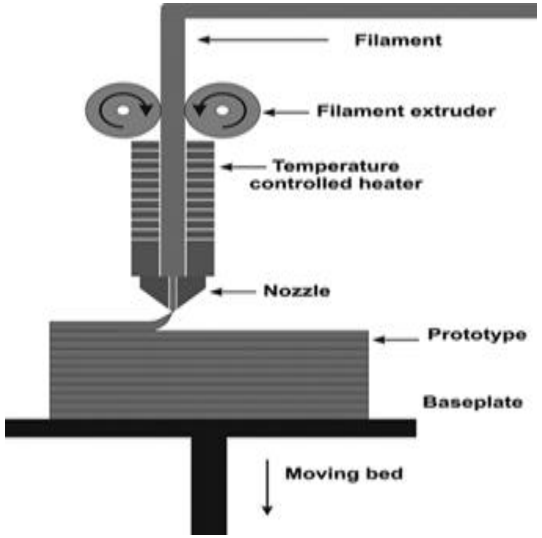
Effect of integrated short & continuous carbon fibers





CONTINUOUS FIBER ADDITIVE MANUFACTURING

Based on the principle of fused filament fabrication (FFF)

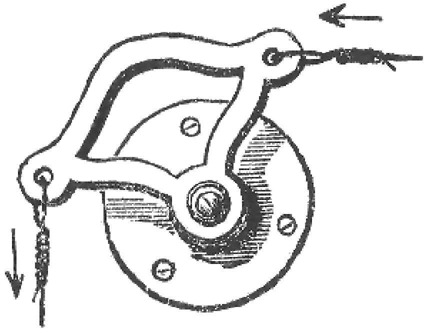


high design freedom in fiber placement

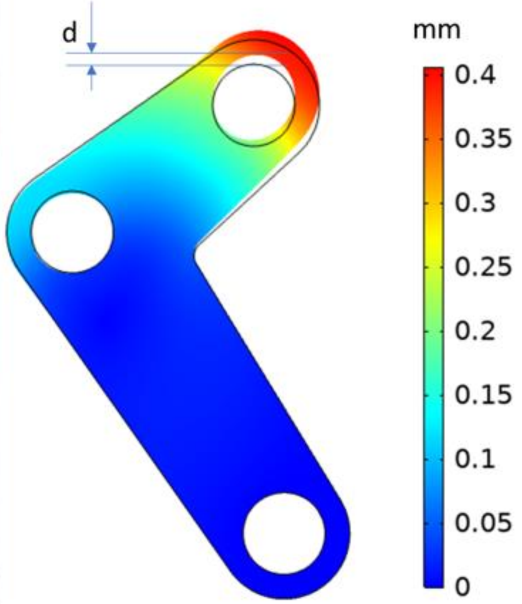
TRANSLATING TO 2D GEOMETRY

Example case: bell crank

- Bell crank: transfer motion in different direction
- **Goal:** Design a lightweight bell crank with maximum stiffness (< 1mm deflection at peak load)
- Compare aluminium product with 3DP composite

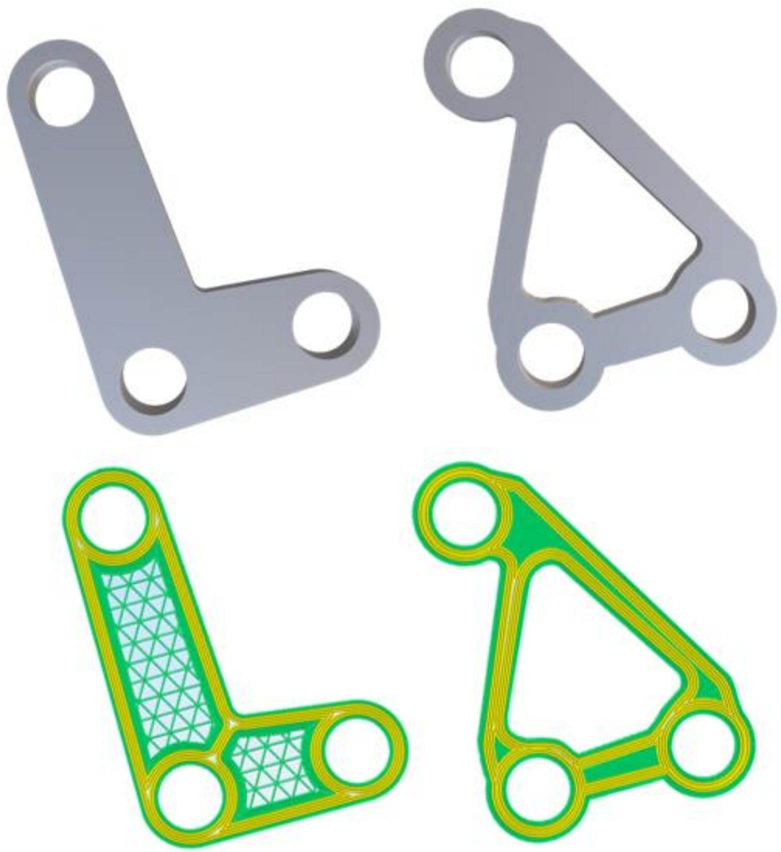


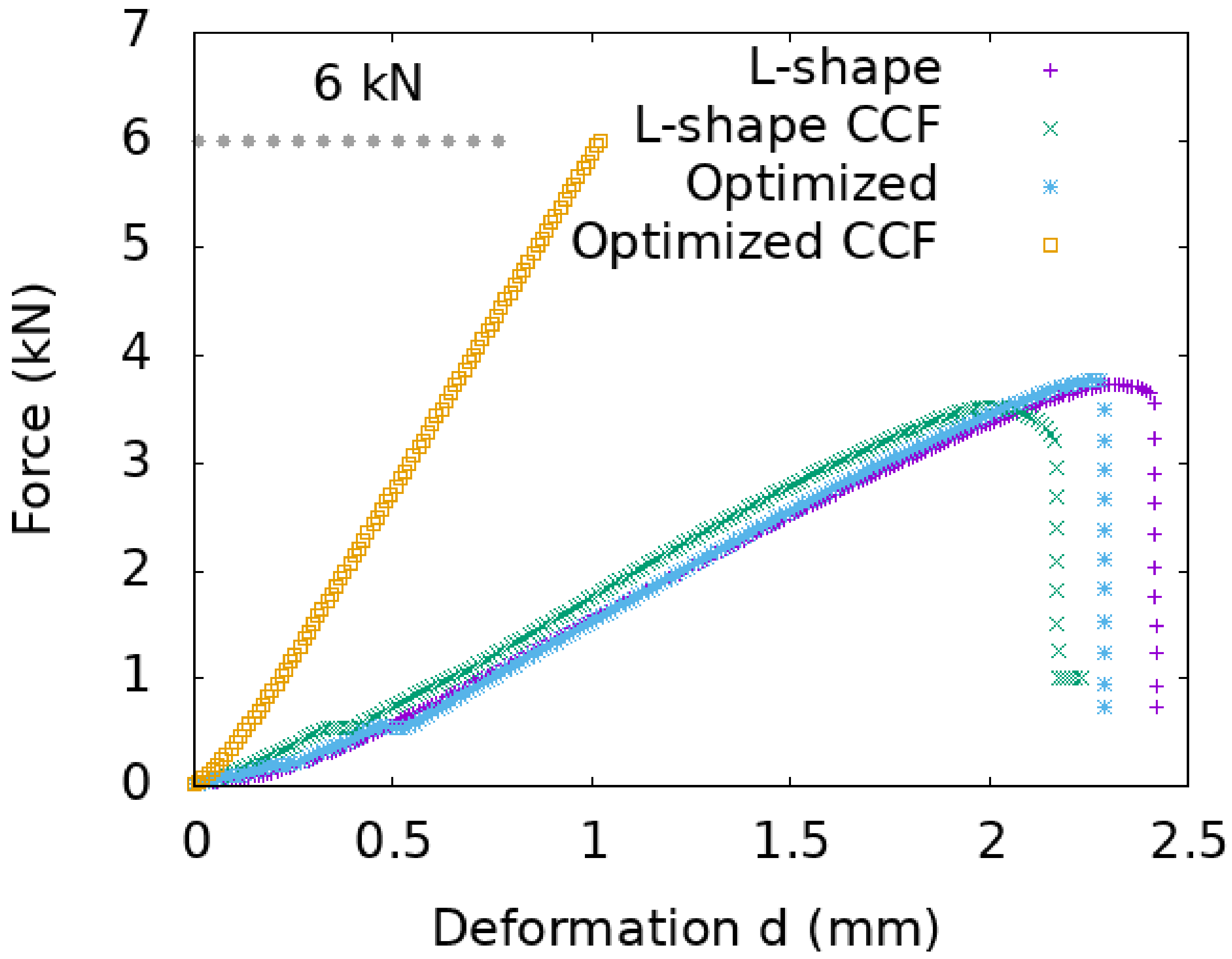
Bell-crank.



OPTIMIZING GEOMETRY & FIBER LAY-OUT

Fitting to 2D load case of bell crank

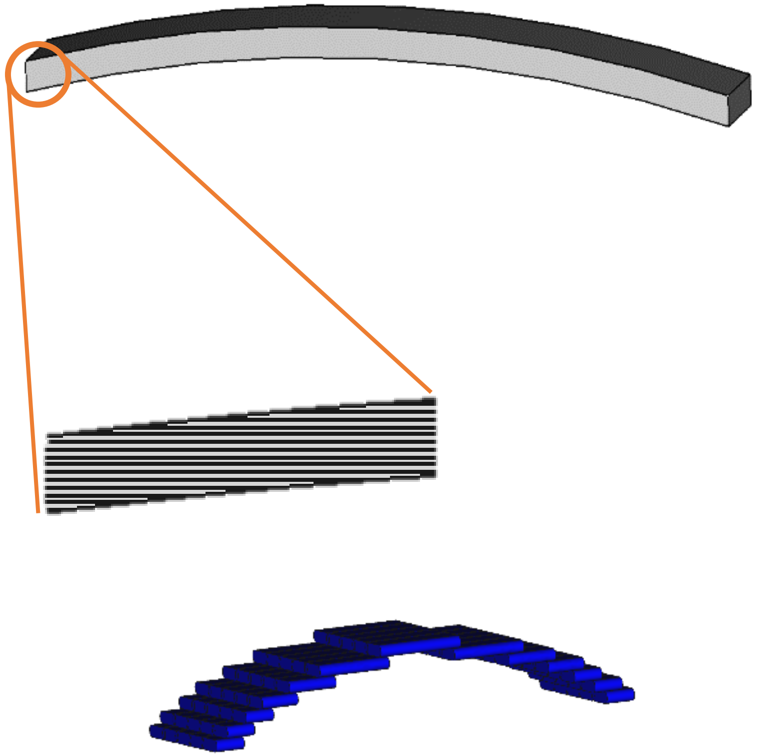




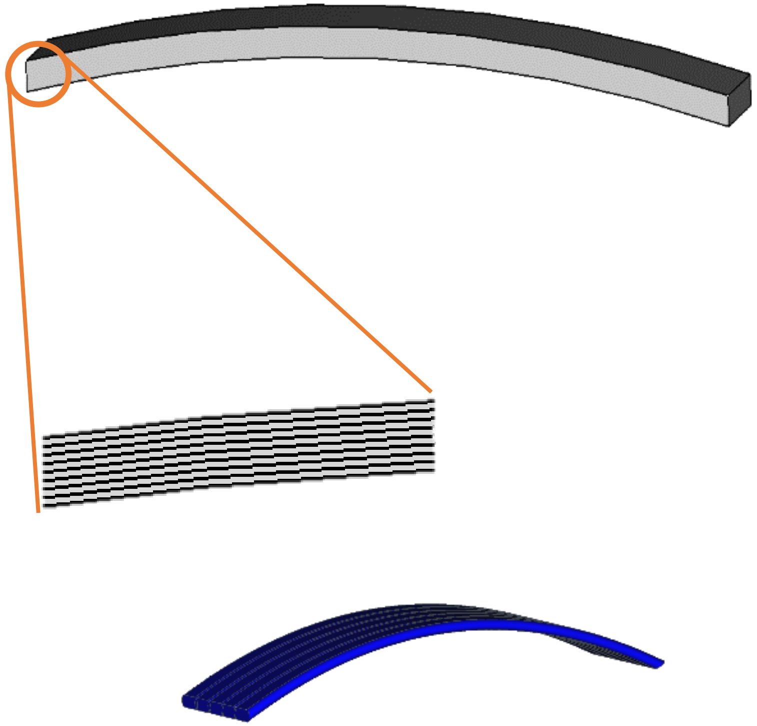
NON-PLANAR PRINTING

Towards conformal fiber lay-out for 3D load cases

Example: curved beam structure printed in planar arrangement



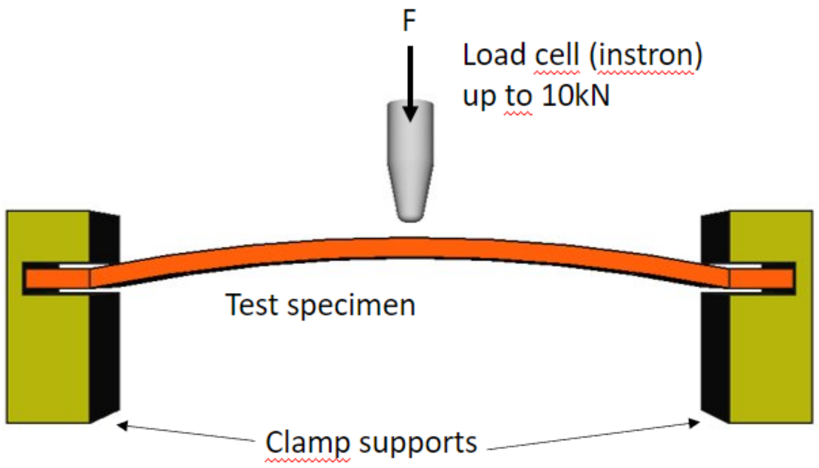
Alternative: curved beam structure printed in conformal arrangement

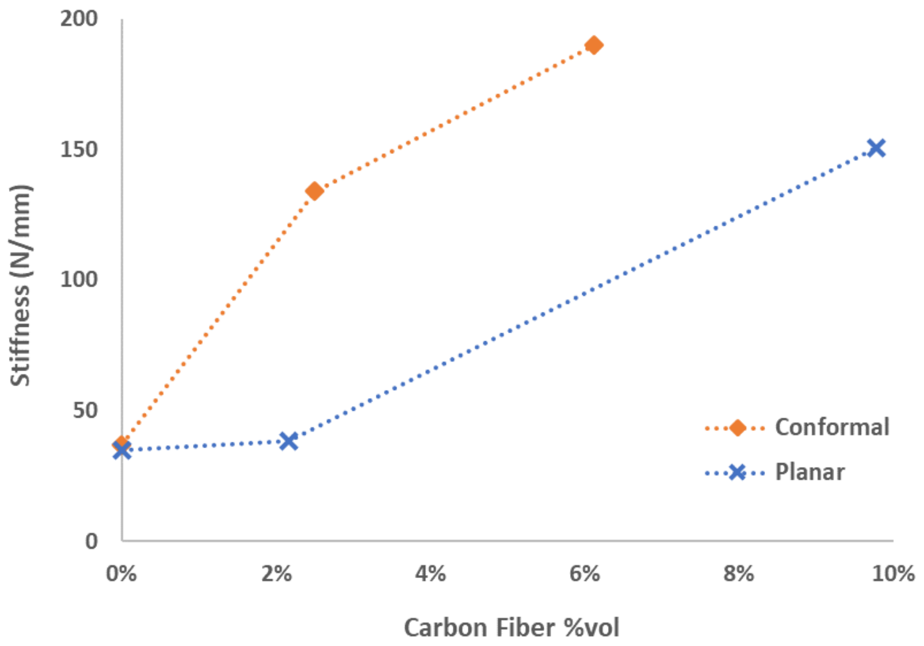


NON-PLANAR PRINTING

Towards conformal fiber lay-out for 3D load cases

PET-G + CCF





- Without CCF reinforcement: no difference in mechanical properties for conformal or planar printing (isotropic properties of unreinforced PET-G matrix)

- For 2.5% CCF reinforcement: more than 3x higher stiffness obtained by conformal printing

LIGHTWEIGHT STRUCTURAL COMPONENTS

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Electrical Motors   Battery Casings   Power Electronics

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SELECTION OF COMPOSITE AM MATERIAL

Combining good mechanical and thermal performance

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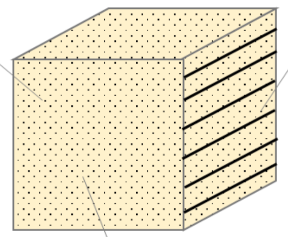

1. Select suitable **polymer matrix** based on use case requirements & printability
   - PA, PEKK, PEI
2. Evaluate effect of **continuous carbon fibers** on mechanical & thermal properties
3. Evaluate effect of **dispersed particles** on mechanical & thermal properties
   - Start with short carbon fibers
4. Select optimized material composition & create **material properties dataset**

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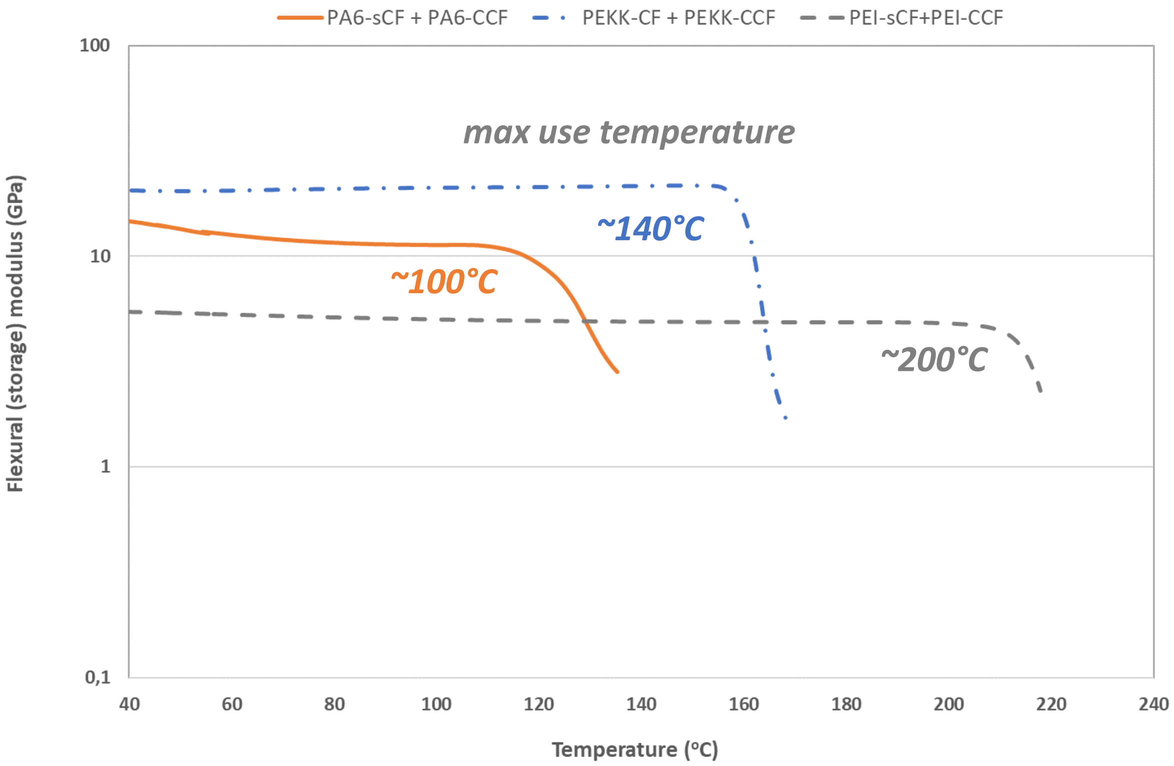
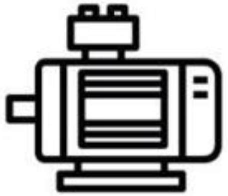
HIGH TEMPERATURE PERFORMANCE

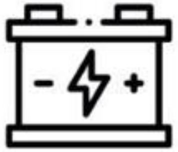
Selecting suitable polymers for different applications



- Thermal stability of PEI (Ultem1010) is best
- BUT: printability of PEKK is better than PEI



Electrical Motors

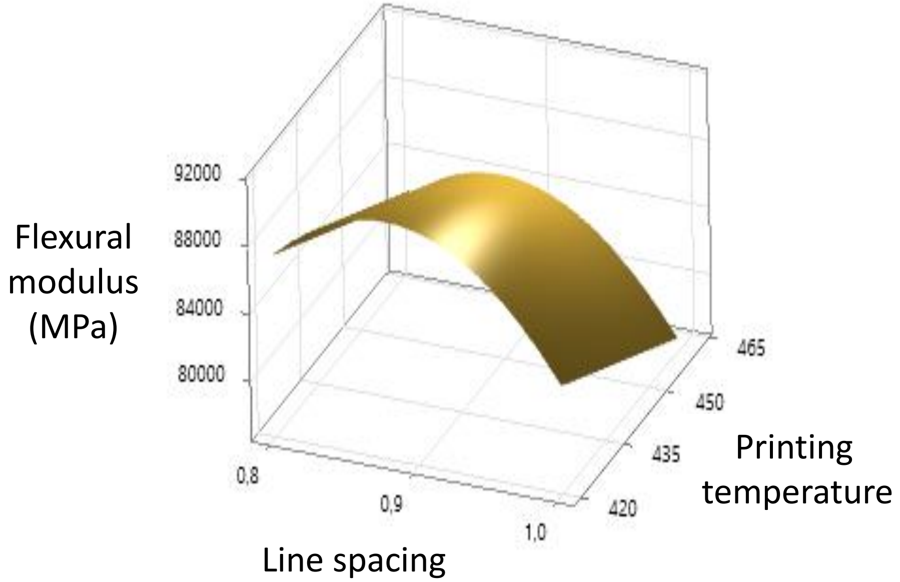


Battery Casings

Power Electronics

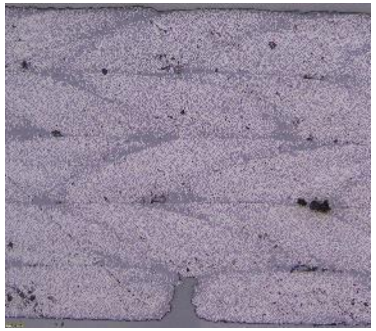
OPTIMIZING PROCESS CONDITIONS

Mechanical performance of PEKK-CCF



Line spacing 1.1

Line spacing 0.9



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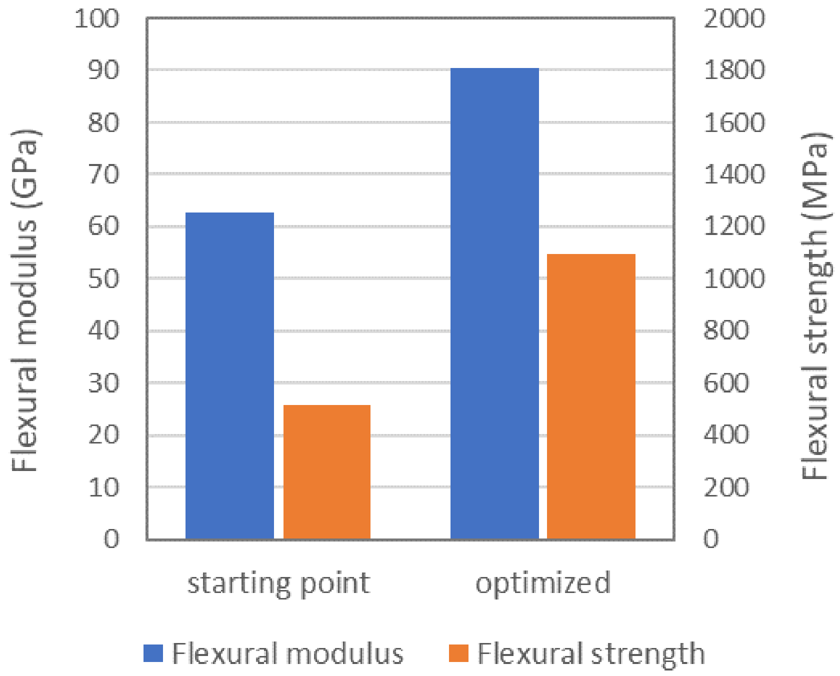
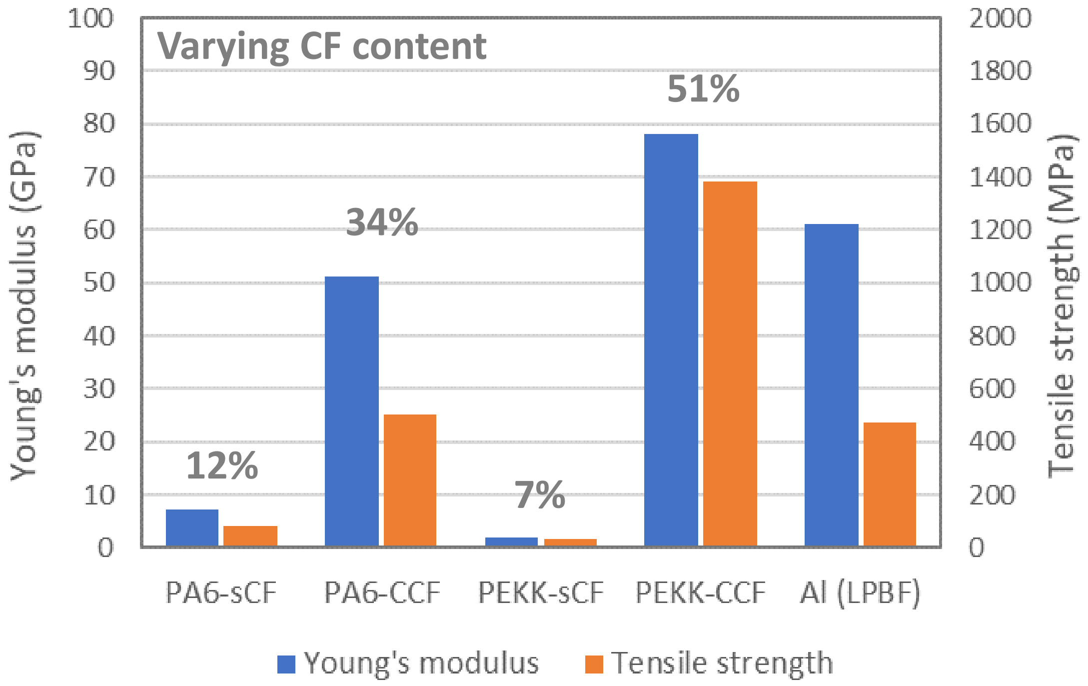
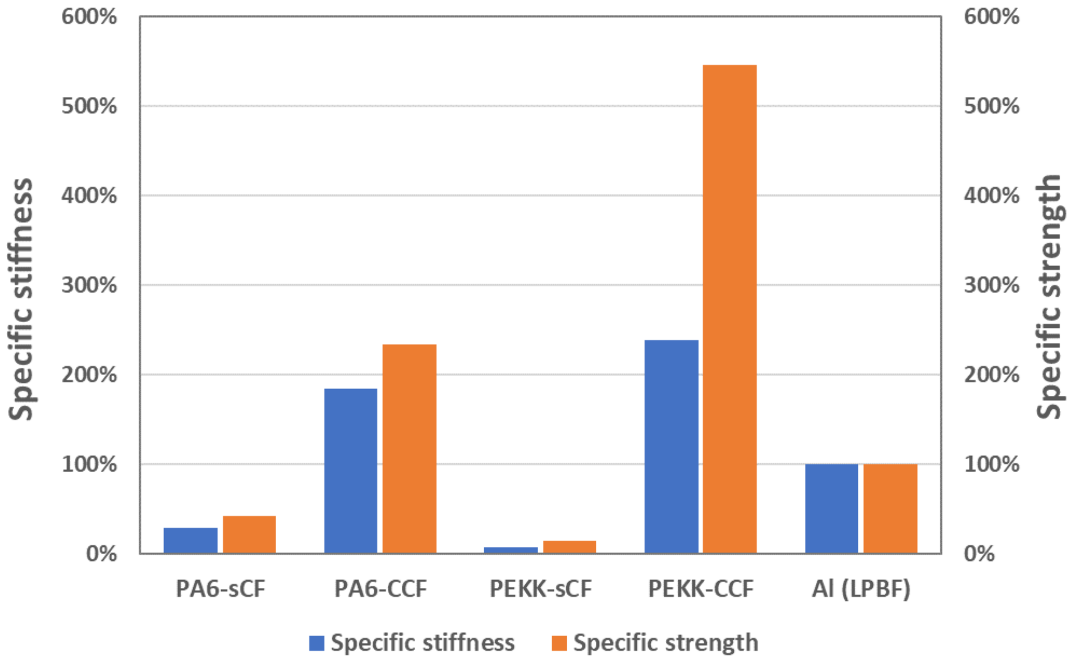


OVERVIEW MECHANICAL PERFORMANCE

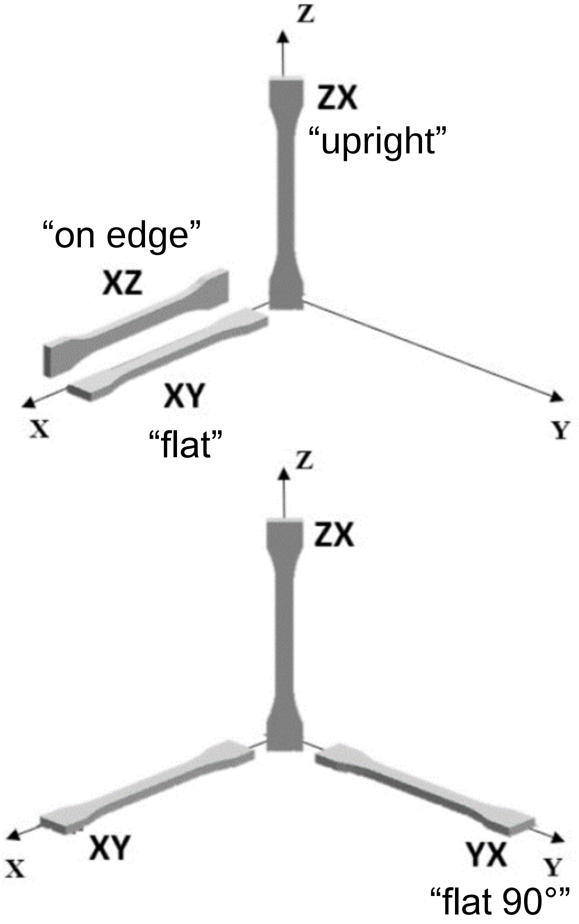
After process optimization

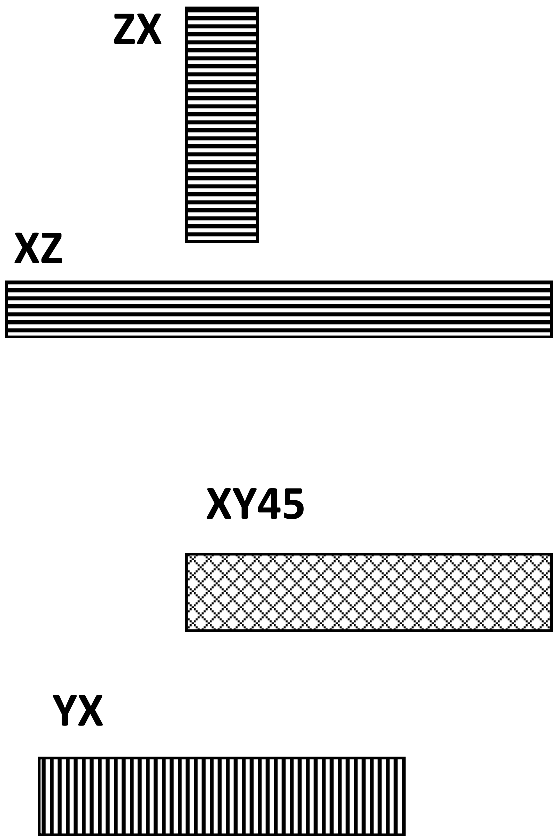


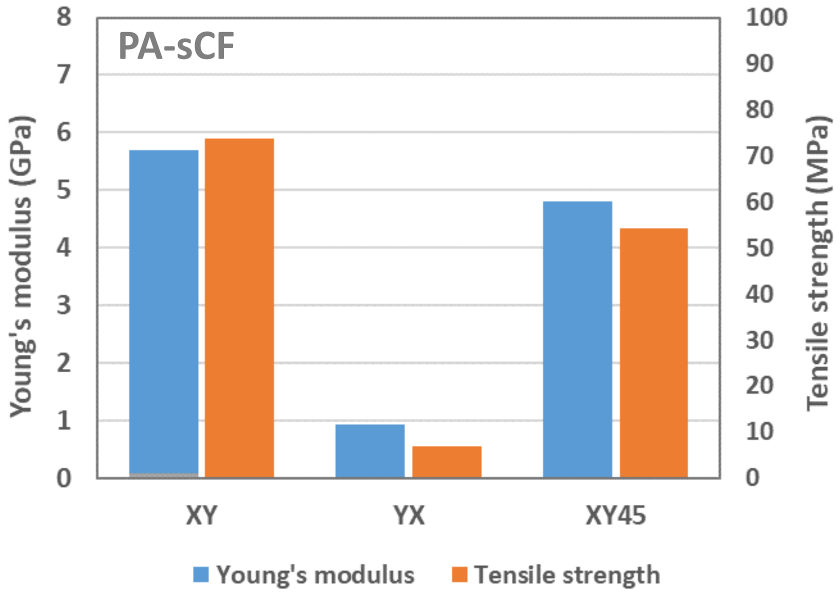


3D MECHANICAL PERFORMANCE

Depending on printing / fiber direction







THERMAL CONDUCTIVITY

Effect of (continuous) carbon fibers

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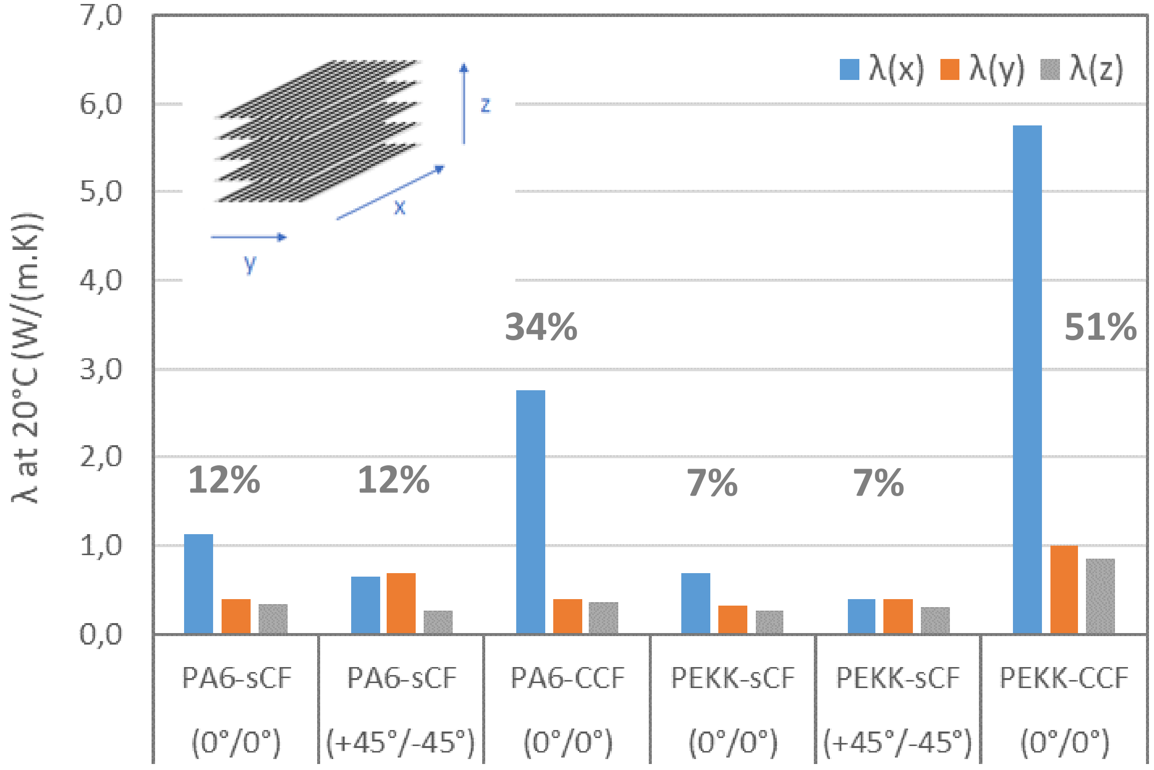
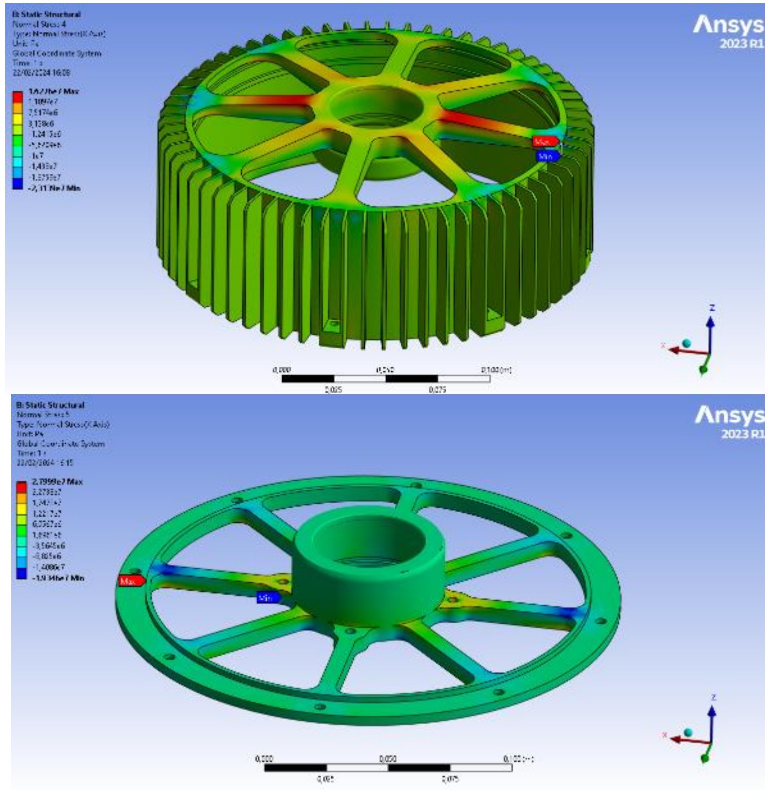


- Carbon fibers increase thermal conductivity, in particular continuous carbon fiber filled materials (which have high CF content)
- Even for short carbon fibers, short anisotropy is created by unidirectional printing
- Homogenized properties in XY plane by printing in +45°/-45° orientation

DESIGN FOR ADDITIVE MANUFACTURING

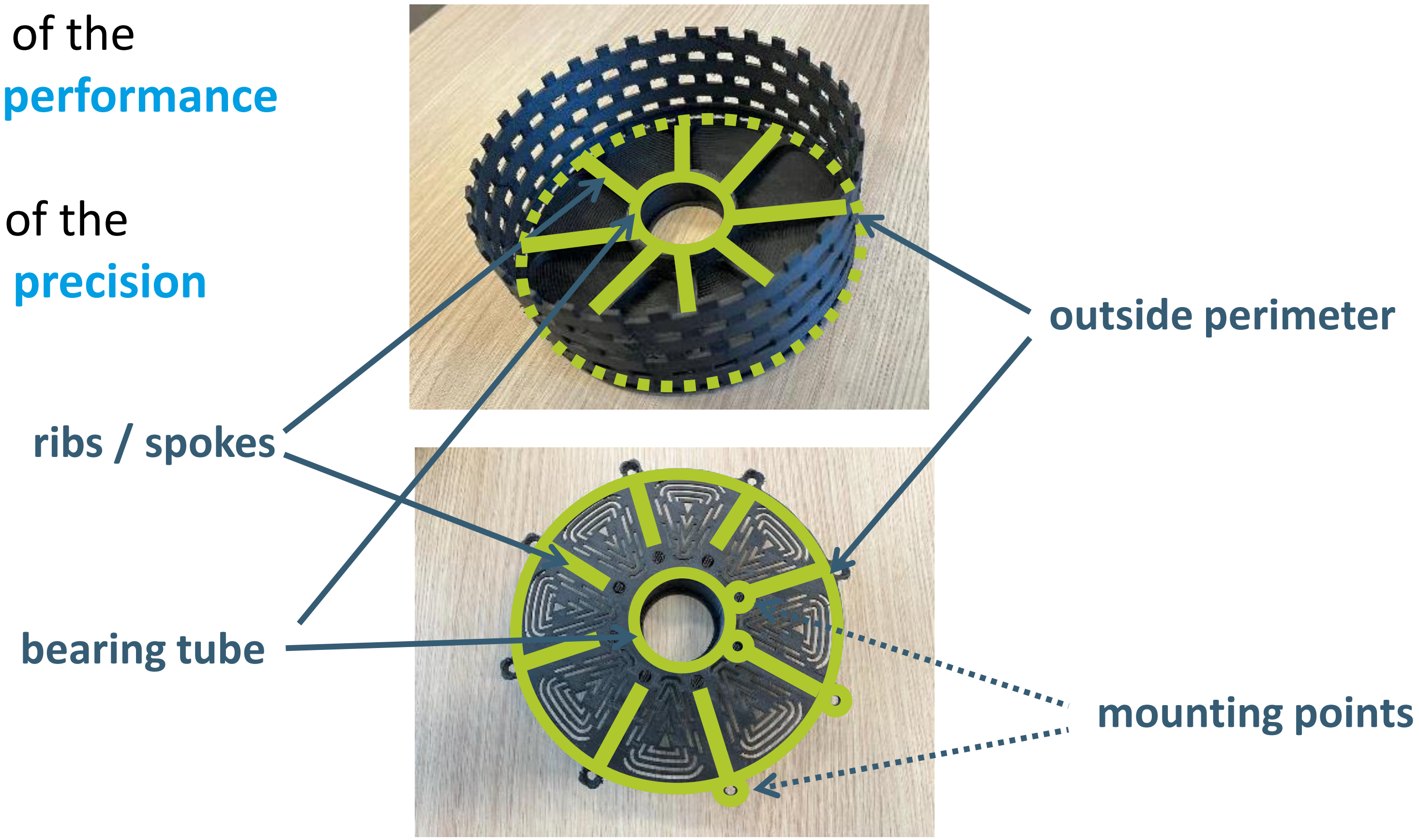
Example: motor housing use case



DESIGN FOR ADDITIVE MANUFACTURING

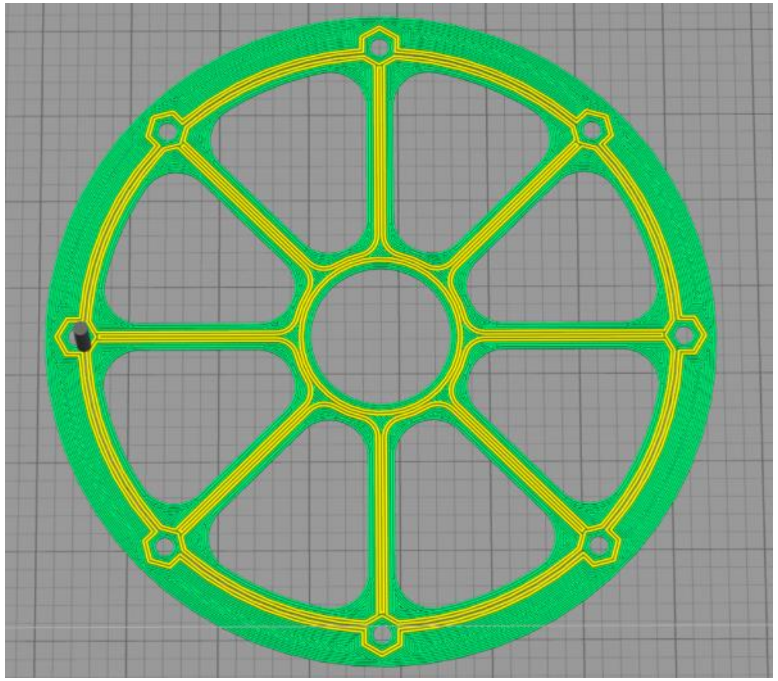
Example: motor housing use case

- Use CCF reinforced materials for parts of the product that require high mechanical performance
- Use sCF reinforced materials for parts of the product that require high geometrical precision

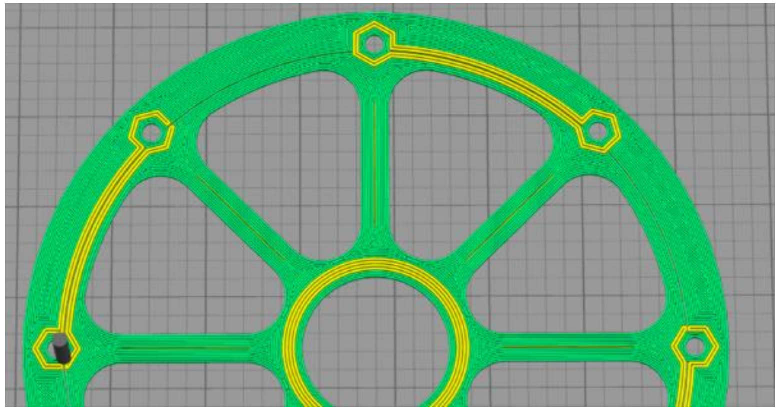


DESIGN FOR ADDITIVE MANUFACTURING

Example: motor housing use case



- Fiber lay-out design strategies to:
  - Support mechanical load case
  - Provide input to (anisotropic) mechanical modelling
  - Optimize printability



CONCLUSIONS & OUTLOOK

- Obtain mechanical properties comparable to aluminum, allowing replacement of metal components by lightweight alternatives
- Thermal management:
  - Good thermomechanical stability
  - Increased thermal conductivity

Next steps:

- Further design & process optimization
- Explore non-planar printing
- Prototype production
- Testing of different use cases

THANK YOU FOR YOUR ATTENTION

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For more information, please contact:

Dr. Tessa ten Cate

Program Manager Sustainable Mobility

tessa.tencate@tno.nl
+31 6 317 52 002

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