DEVELOPMENT OF A MANUFACTURING PROCESS FOR CONTINUOUS FIBRE-REINFORCED PRINTING FILAMENTS

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Motivation FIONA project

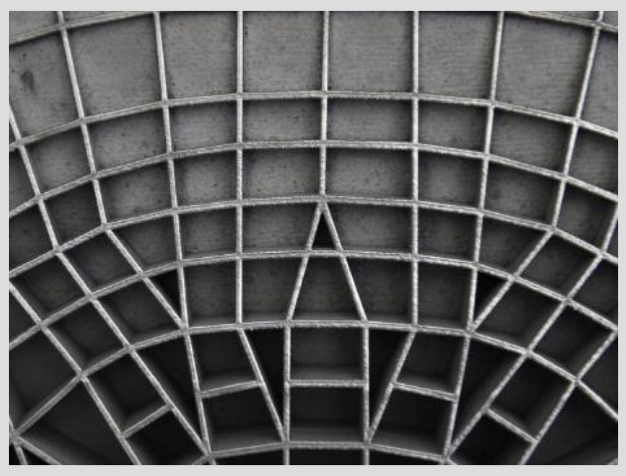
- Additive manufacturing (AM) processes are establishing themselves as recognised processes.
- Due to a lack of process maturity, products are only used for components subject to low loads.
- AM with continuous fibre reinforcement offers the possibility of functionalising components.
- AM has the potential for a tool-less production of fibre-reinforced composite parts.
- The printing filaments are not available in sufficient quality or performance.

  → Development of suitable continuous fibre-reinforced printing filaments is necessary.

Funktions-**I**ntegrierte **O**ptimierte **N**euartige **A**dditive Strukturen

Function-**i**ntegrated **o**ptimised **n**ew types of **a**dditive structures

FIONA project logo



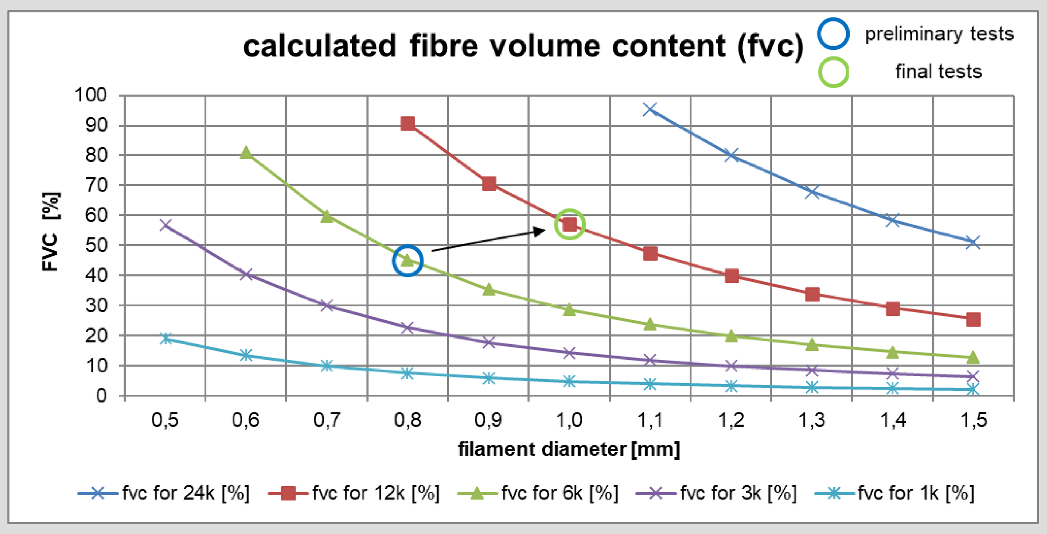
Functionalised 3D printed structure (© dpa / Carmen Jaspersen)

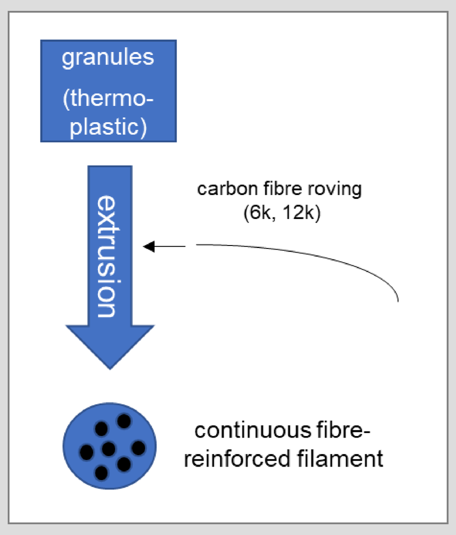
Goals and used materials

- Process development for the manufacturing of continuous fibre-reinforced printing filaments
- Utilisation of a high temperature thermoplastic as the appropriate polymer matrix
- Carbon fibre rovings are used for the continuous fibre reinforcement
- Target filament diameter: 1.0 mm with a fibre volume content (fvc) of 50 % - 60 %

  → Polymer matrix: high performance thermoplastic material (e. g. PPS, PEKK, PEEK)

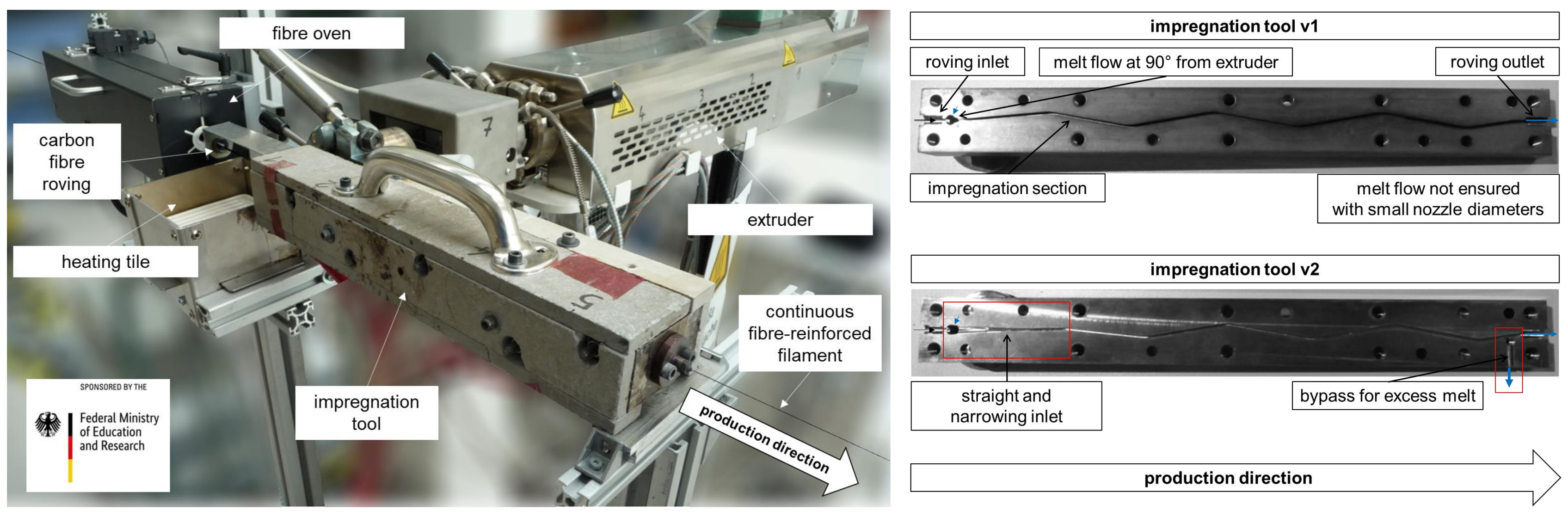
  → Carbon fibre rovings: various types, aviation approved carbon fibre (6k → 12k)





Extrusion process

- An impregnation tool is used to manufacture the continuous fibre-reinforced filaments.
- Carbon fibre roving is preheated via fibre oven and heating tile (temperature: 250 °C).
- Thermoplastic material is extruded into the connected impregnation tooling.
- Meandering impregnation section in the tool, which is set to 400 °C to 380 °C (5 zones).

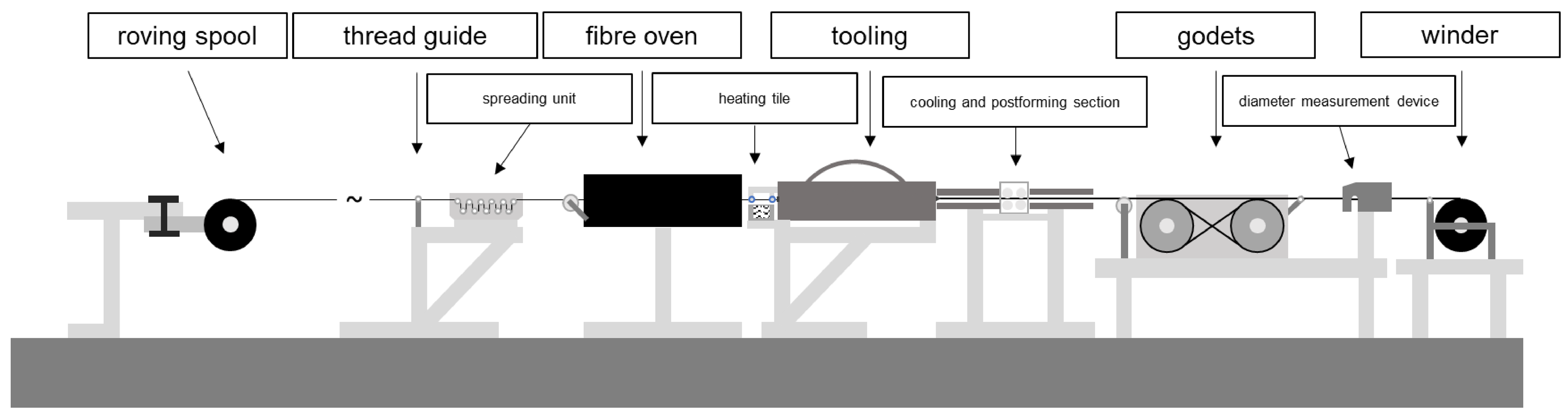


Experimental setup for manufacturing of continuous fibre-reinforced filaments (left) and impregnation tool (right)

(extruder: Teach Line® E 20 T x 25 D by COLLIN Lab & Pilot Solutions GmbH)

Process optimisation

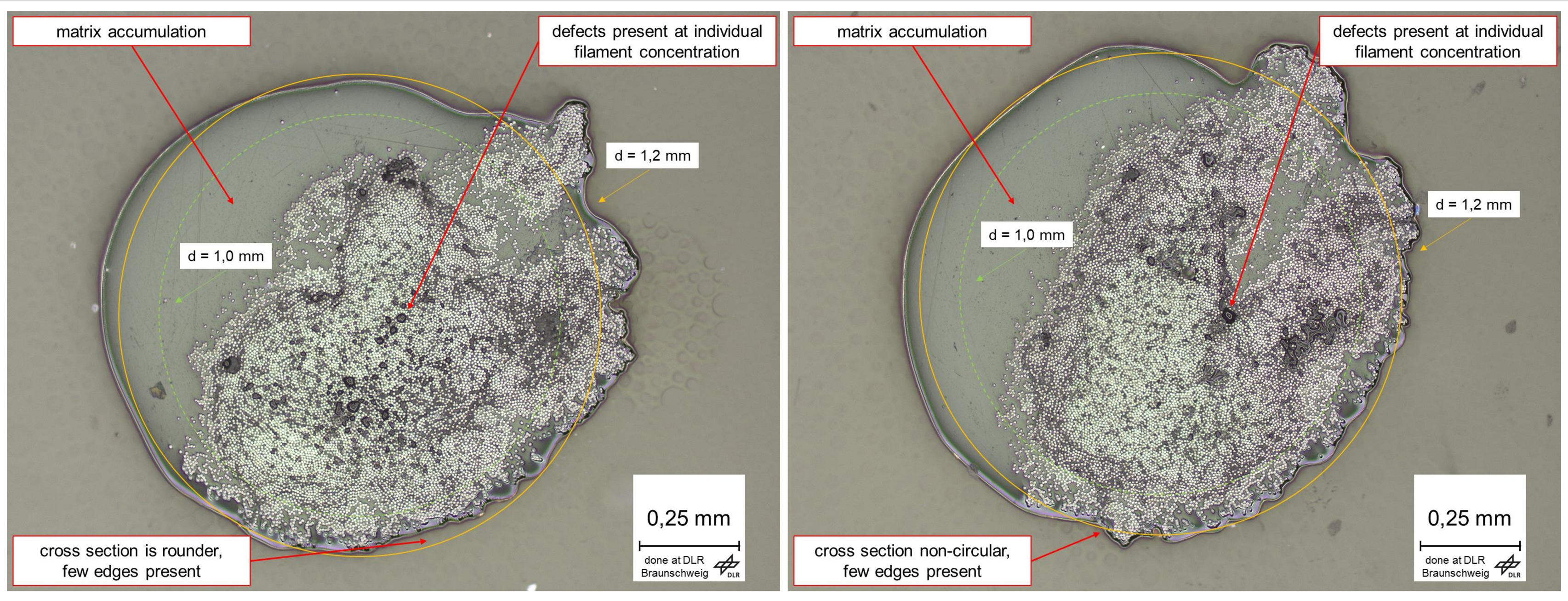
- Increased distance between roving spool and tool for untwisting of the carbon fibre roving
- Spreading device to separate carbon filaments during preheating for easier impregnation
- Additional fibre oven to improve the preheating of the carbon fibre roving prior to tool inlet
- Cooling and postforming section after tool outlet to conserve round filament geometry
- Galettes for better control of the pull-off speed of the filament at high mould cavity pressures
- Larger filament spools (inner diameter = 305 mm) to bend filaments respectively fibres less



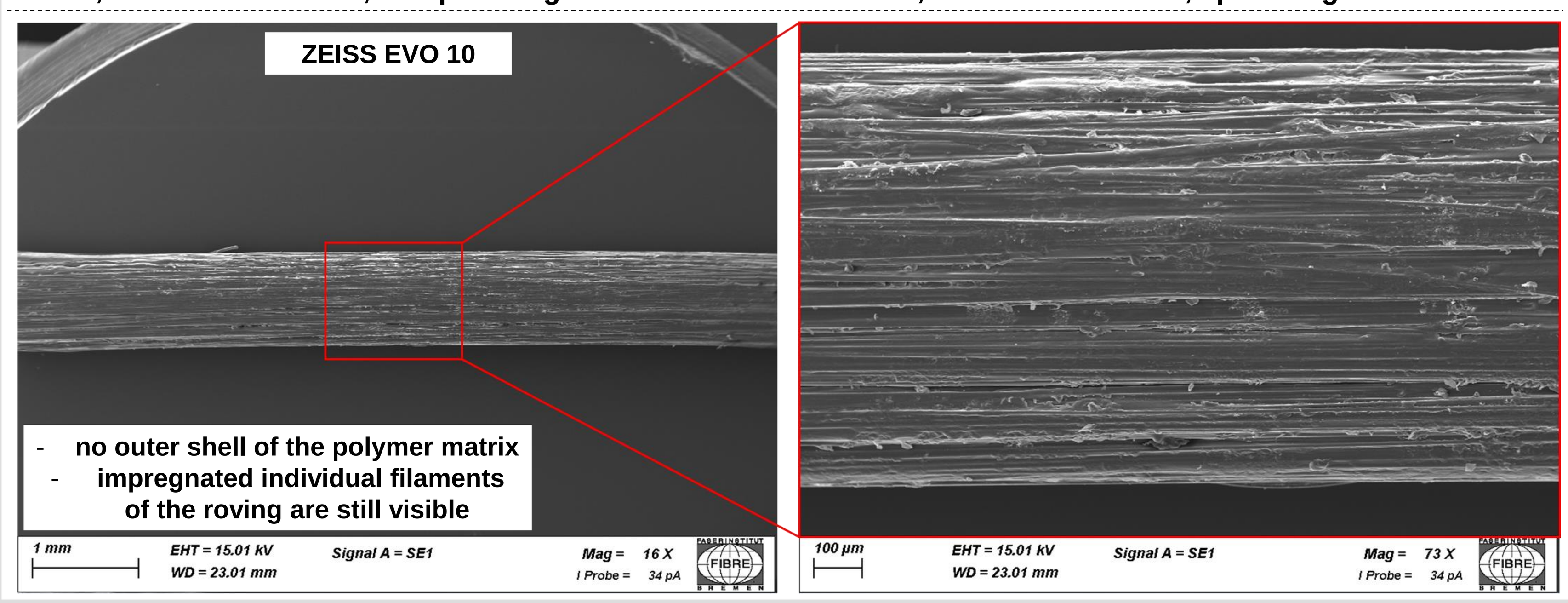
Sketch of the optimised experimental setup for the manufacturing of continuous fibre-reinforced filaments

(extruder positioned at a 90° angle behind the tool)

Results: Micrographs & SEM imaging

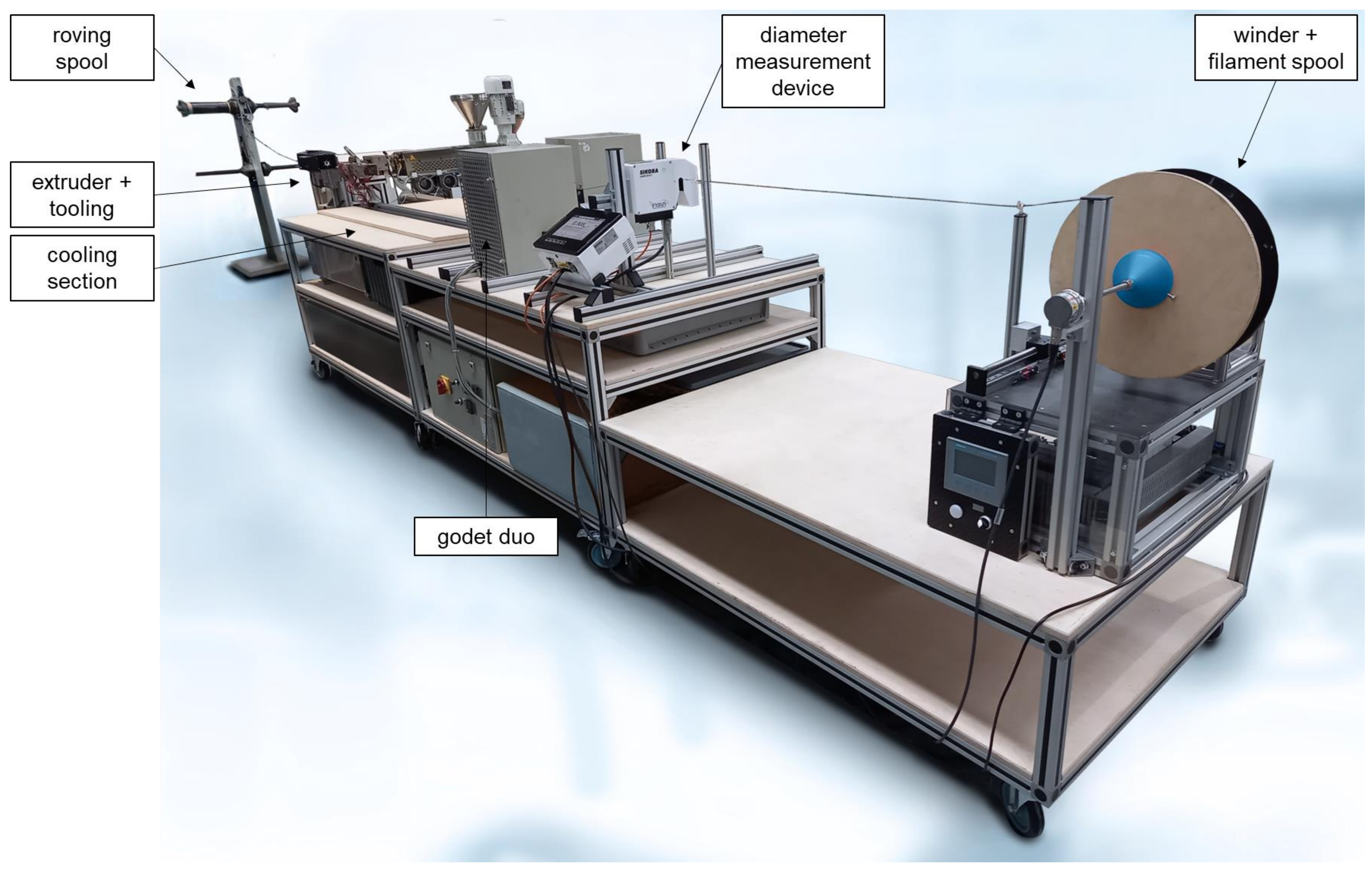


PEKK matrix + carbon fibre roving (12k) melt pump = 4 rpm, pull-off speed 1,5 m/min 1,0 mm outlet nozzle, no spreading unit used → **PEKK matrix + carbon fibre roving (12k) melt pump = 4 rpm, pull-off speed 1,5 m/min 1,0 mm outlet nozzle, spreading unit used**



Outlook further developments

- Manufacturing process adaptation and matching of fibre and matrix to develop a robust and process-stable 3D printing filament made of high-performance polymers (e. g. PEEK, PEKK, …)
- Development of a modular tool to improve the individual carbon fibre impregnation
- Improve the cooling and postforming section in terms of target diameter and roundness
- Manufacturing process optimisation for the continuous fibre-reinforced printing filaments
- Evaluation of the filament manufacturing process



Optimised experimental setup for the manufacturing of continuous fibre-reinforced filaments

(spreading unit and postforming section not included)

Conclusion

- Innovative manufacturing methods for continuous fibre-reinforced 3D printing filaments were developed in the FIONA project.
- The process optimisations have significantly improved the impregnation and distribution of the individual filaments across the cross-section.
- The filaments produced show minor defects and edges in cross-section, which will be further optimised in the course of the project.
- The focus of further developments will be on redesigning the tool (impregnation) and optimising the cooling and postforming section (target diameter & roundness).

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ZIM Zentrales Innovationsprogramm Mittelstand

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