Low cost rapid prototyping manufacturing process for tailored fiber placement components

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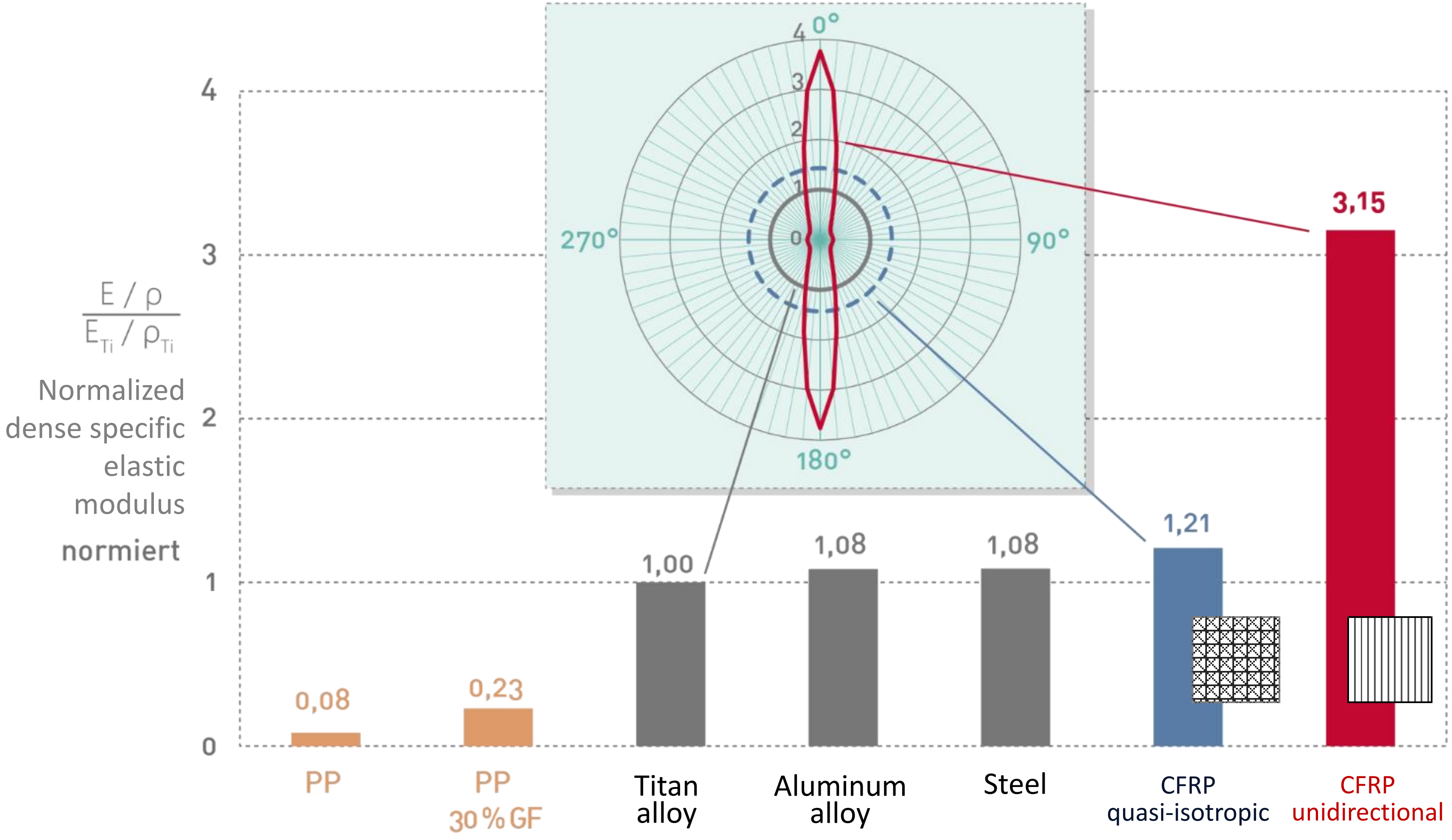
Outline

- Tailored Fiber Placement
- Different approaches for 3D printed molding tools
- Means to improve component quality
- Example of a complex geometry
- Conclusion

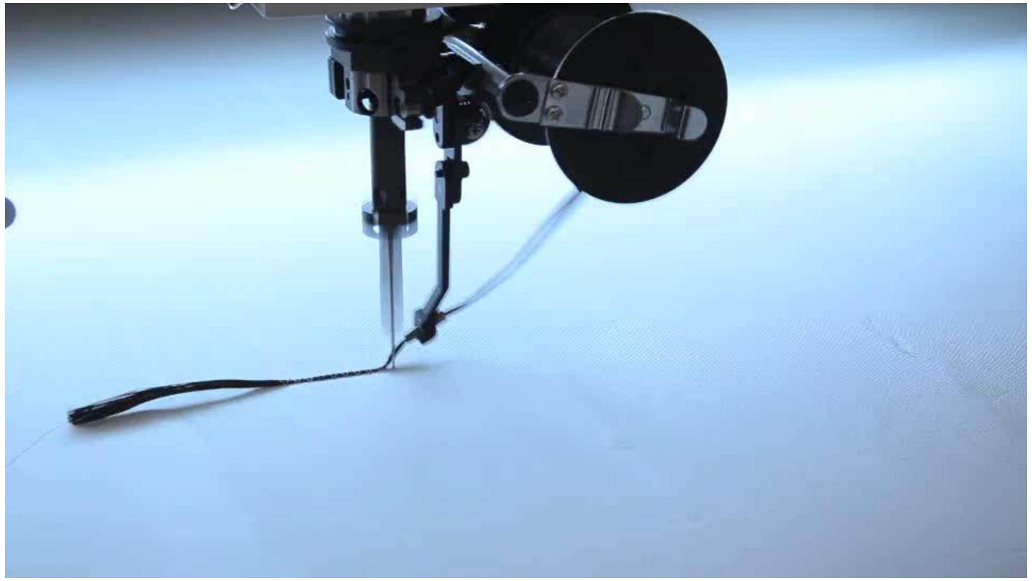
Properties of different materials

Normalized dense specific elastic modulus of different lightweight material



Tailored Fiber Placement (TFP)

- Near-net-shape production of variable-axial textile preforms
- Almost ideal utilization of anisotropic material properties
- Placement radii up to 5 mm

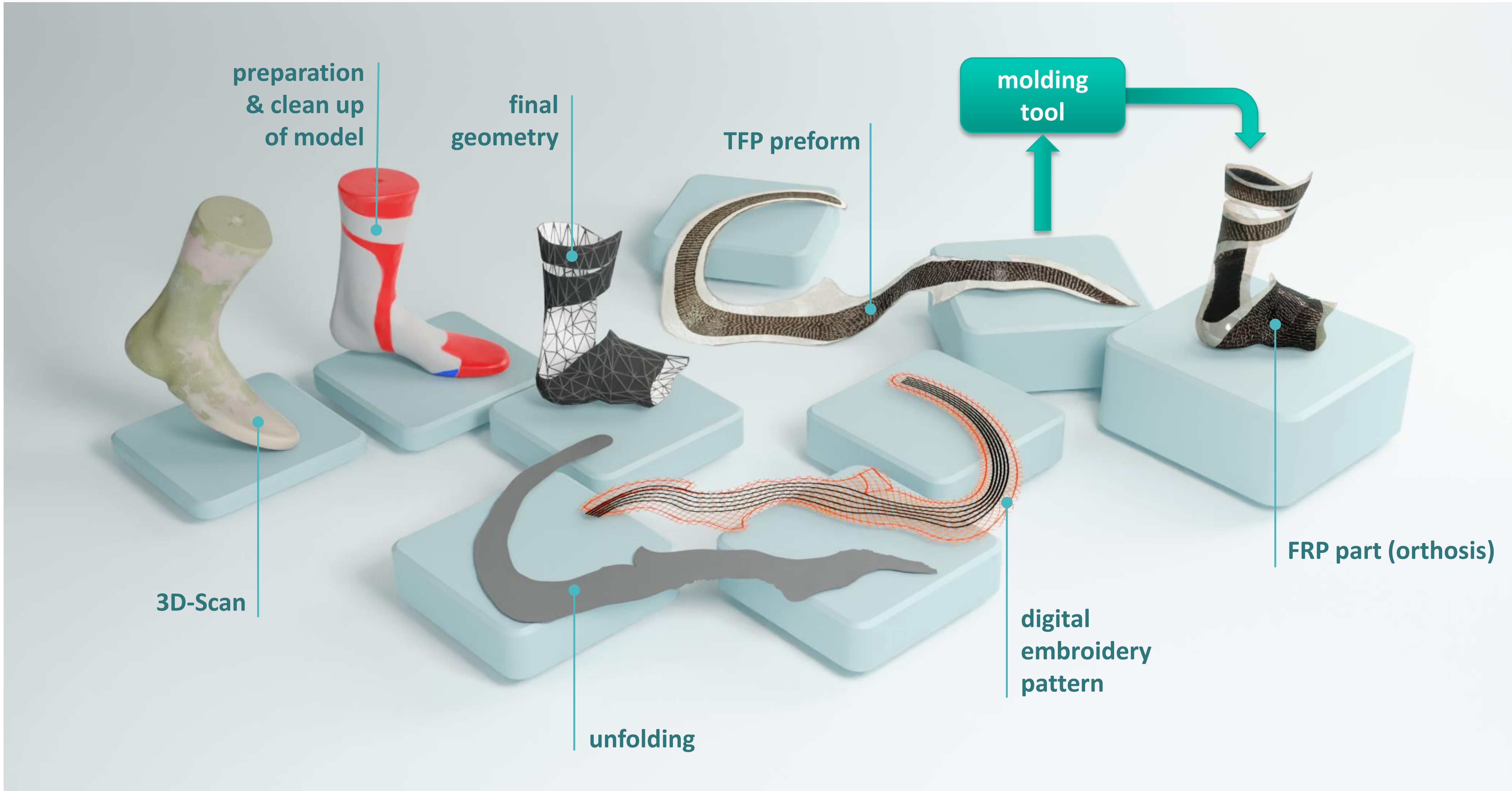


But…

… complex part surfaces
(depending on component)

Complex molding tools required

Workflow from 3D Scan to embroidery pattern



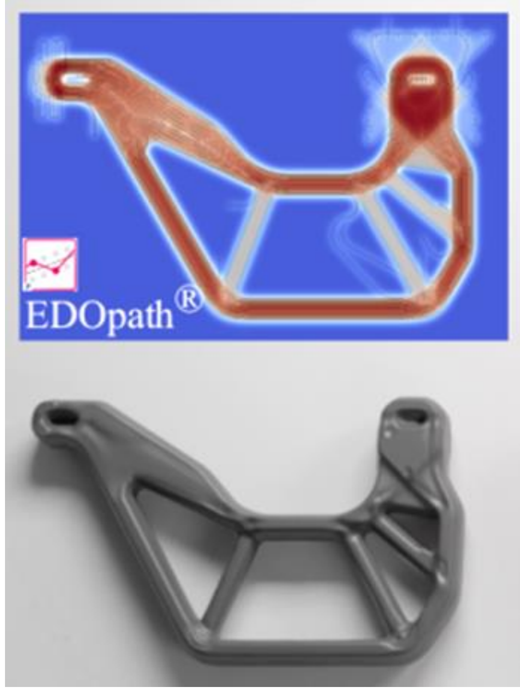
Molds for TFP components

- Characteristic TFP surface often requires **3D milling**
  - ➢ Surface quality
  - ➢ Reusability
  - ➢ Time consuming mold production
  - ➢ Costly (esp. for prototypes and very small series)

- Utilizing **3D printing** (Fused Deposition Modeling) technology
  - ➢ Cheap process
  - ➢ Comparatively fast
  - ➢ Surface quality
  - ➢ Limited lifetime of mold (not relevant for small series)

- Silicone molds cast from 3D printed parts
  - ➢ Easy demolding
  - ➢ Allows undercuts in geometry (simplifies CAD design)
  - ➢ Still inexpensive

Thickness profile of TFP part



Approaches for molding tools obtained by 3D printing

Infiltration performed on	Single sided mold (only one surface of part definded)	Closed mold (defined surface over entire part)
3D print	+ fastest - worst surface quality ~ 2 days	+ still fast, - more parts to print - limited mold reusability ~ 3 days
Silicone mold	+ easier demolding - at least +4h for casting and curing of silicone 2-3 days	+ best surface - mold design more complex - „slowest“, but still fast 3-5 days

(Optional)

Acetone smoothing of print surface

+ 3h

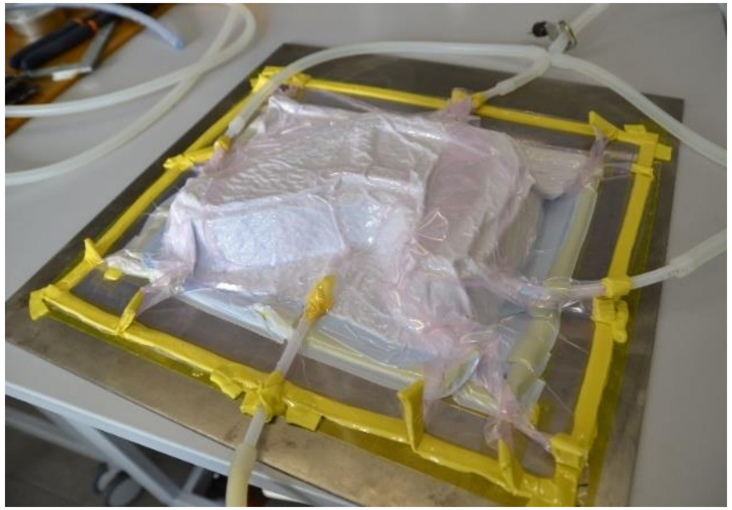
(requires ABS as print material)

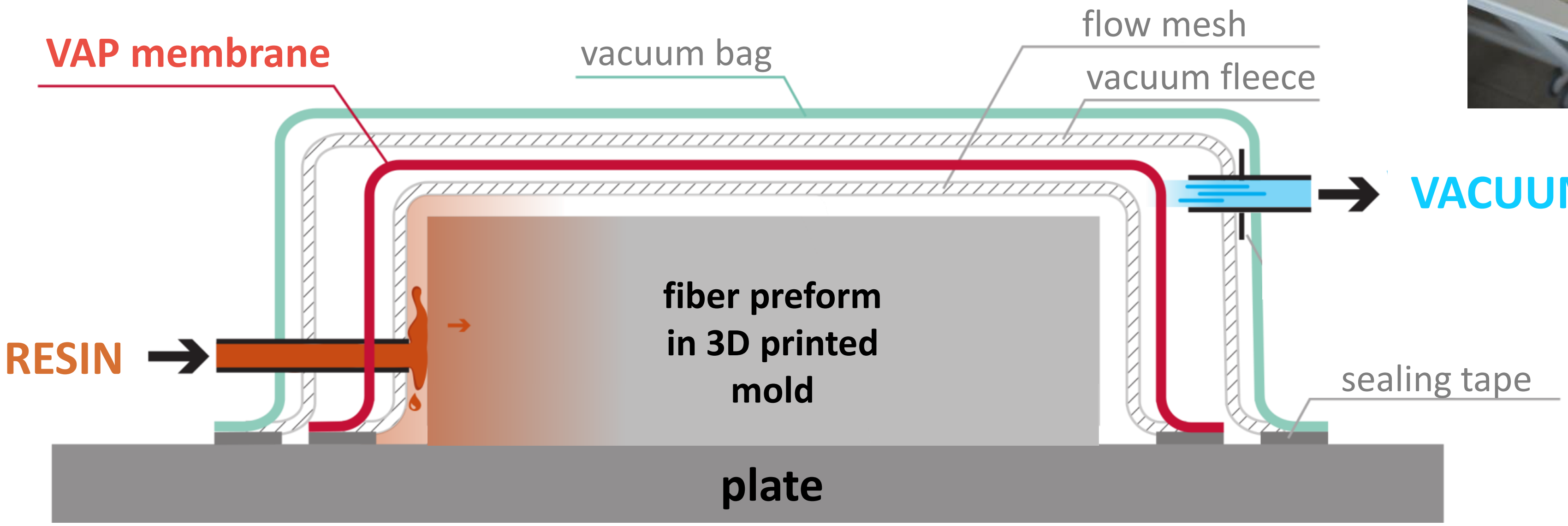
Smoothed surface transfers to FRP part

Time from CAD model to manufactured FRP prototype

Vacuum Assisted Process (VAP)

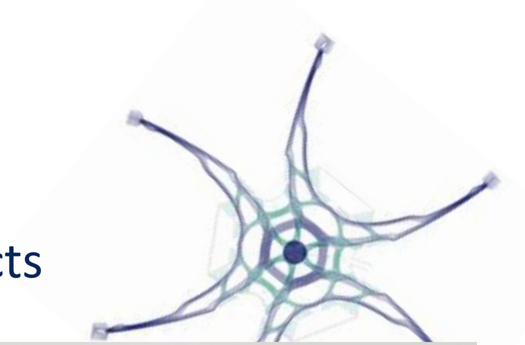
- Basis for all presented methods
- Printed molds and preform enclosed in semipermeable membrane





Single sided 3D printed mold *(Stool „L1“ miniature)*

1. Four piece negative open mold design
2. ABS print used with mold release for easy demolding
3. Finish: Sanding and clear coat to remove 3D print artefacts



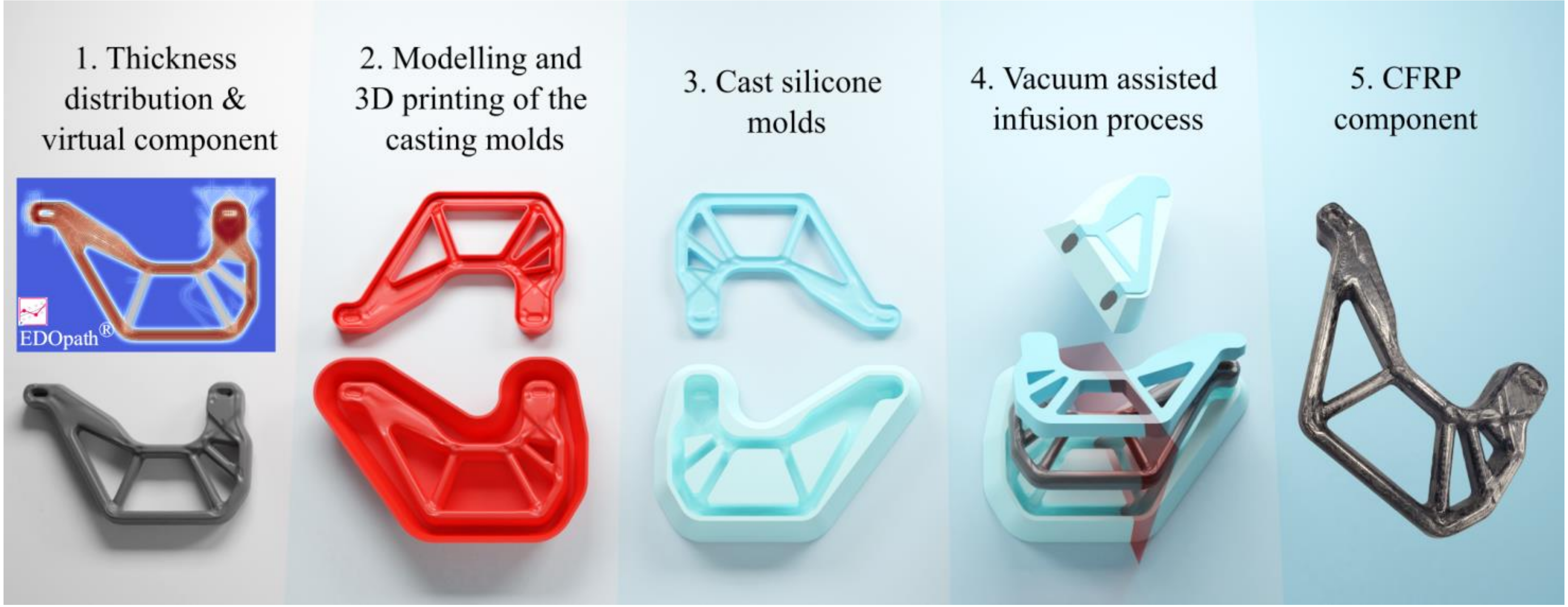
“Misuse” load case experiment

Production time (miniature)
- mold design, printing and acetone smoothing (2,5 days)
- Infusion and finishing (2 days)

= 4,5 days

	Miniature	Original
Height	15 cm	50 cm
Weight	37 g	650 g
Load case	-	200 kg

Closed mold design for 2.5D components (silicone)



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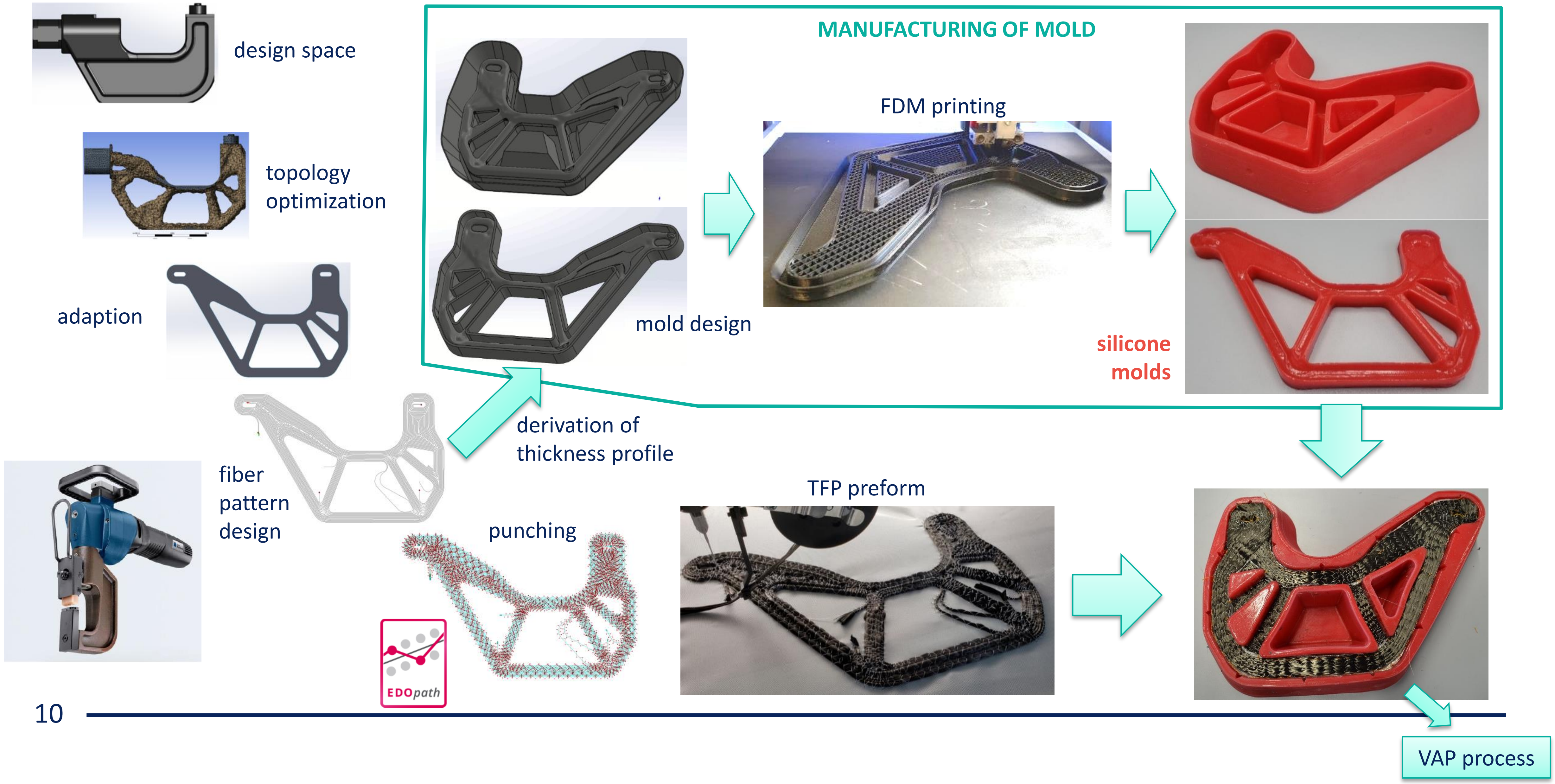


Means to increase dimensional stability

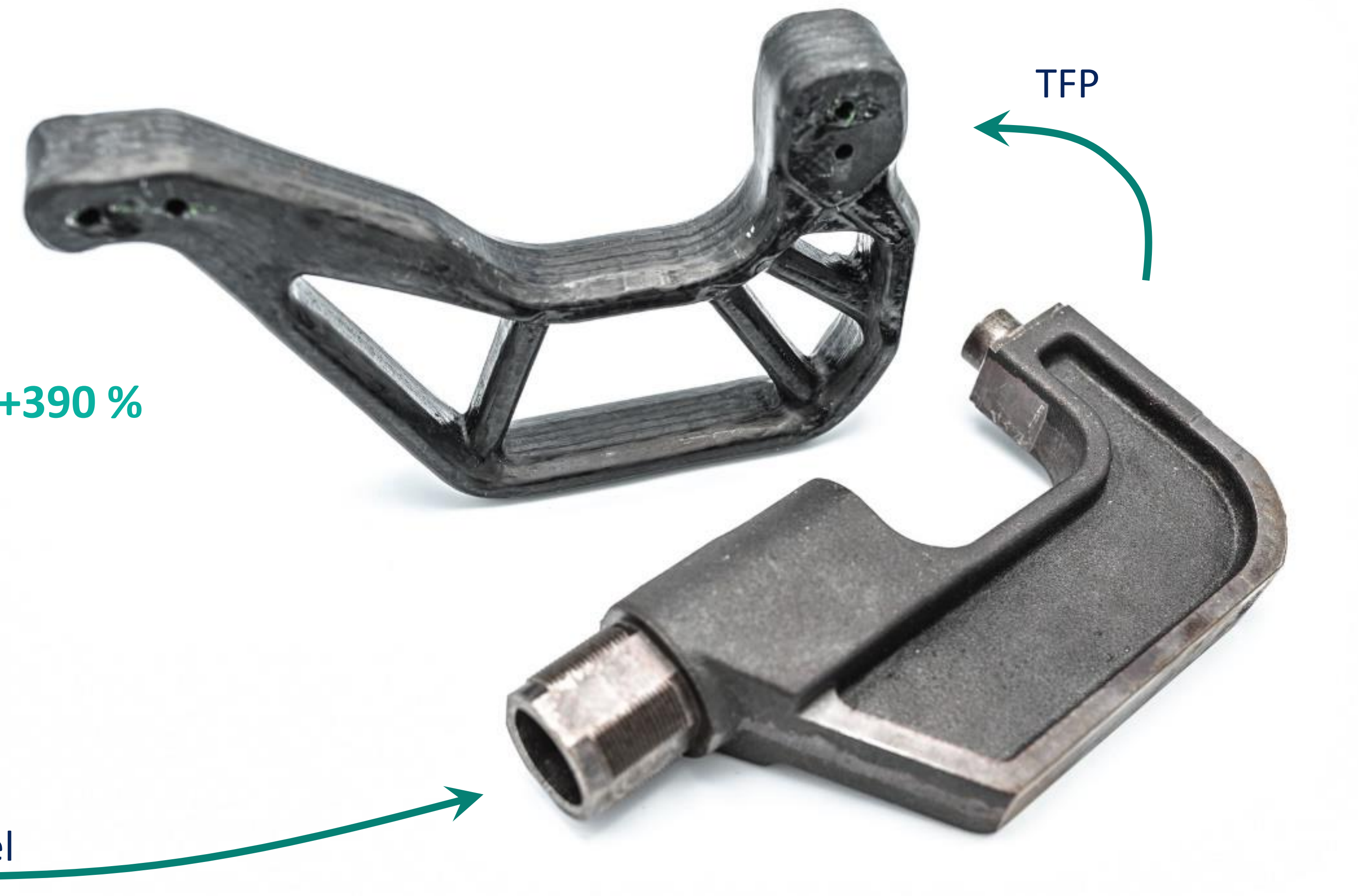
Target: Prevent stretching of silicone

- Space for resin inserts inside of mold
  - ➢ easier inserting of preforms
  - ➢ easier demolding
- 3D printed frame around silicone

C-frame

- **Mass reduced**
  from 2.5 kg (steel)
  to 0.5 kg (TFP)
  -80%
- **Same stiffness**
  16.5 - 17 kN/mm

➢ **Mass specific stiffness** increased by **+390 %**



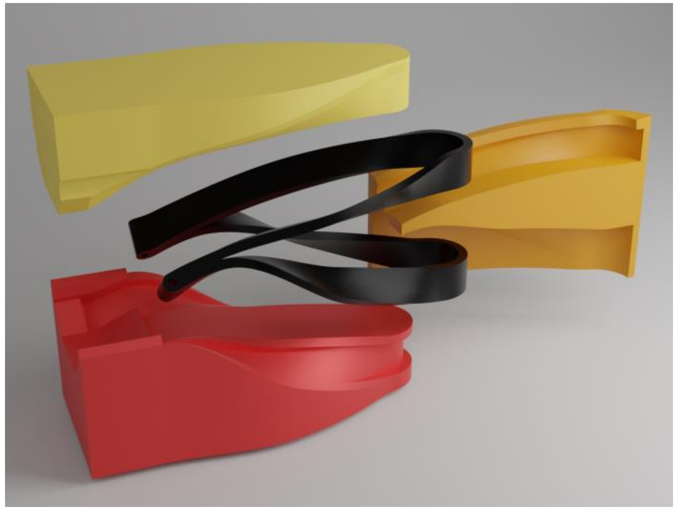
Complex 3D part

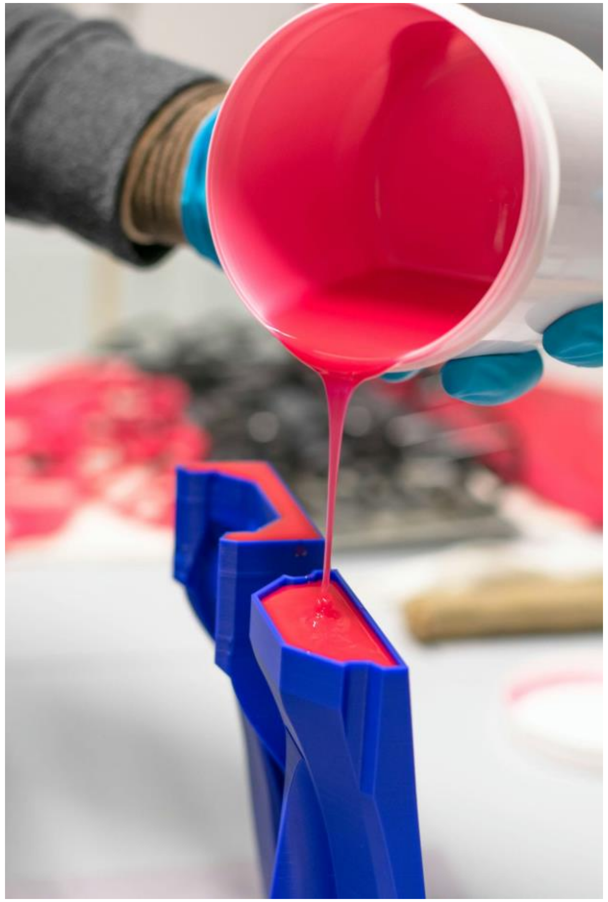
Design concept by HTW Dresden to provide support walking

- Part design (CAD) by HTW Dresden
- Mold design and manufacturing of FRP prototype (TFP) realized by IPF
- Post-processing of prototype carried out by HTW Dresden

ExoWalk TFP prototype

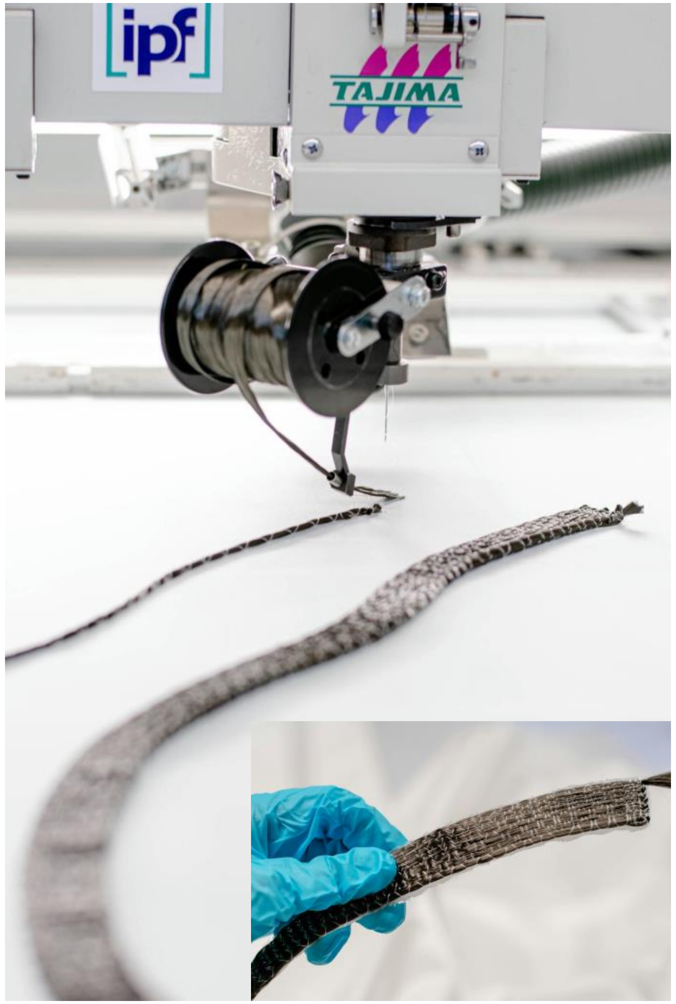
Mold design and manufacturing





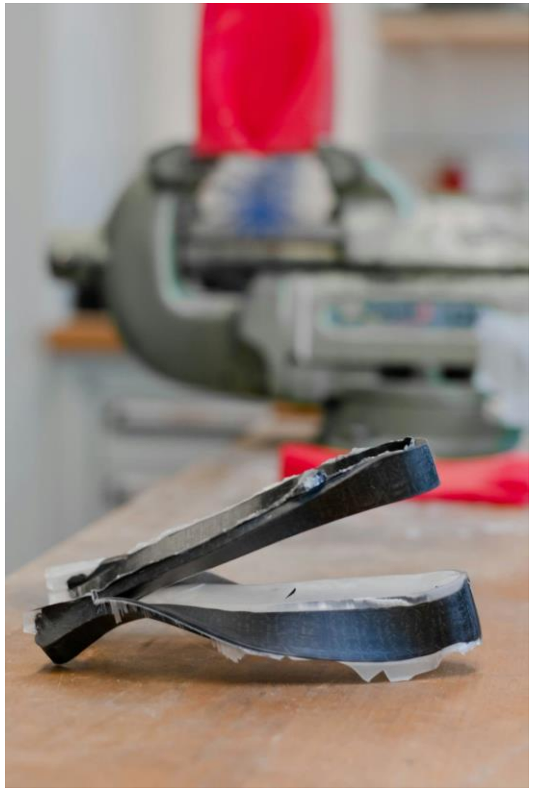
ExoWalk TFP prototype

TFP preform and setup of VAP process



ExoWalk TFP prototype

Demolding and post-processing



ExoWalk TFP prototype

Finished prototype

after sanding

after clear coating

Comparison of different types of tool manufacturing

Manufacturing method	Conventional (milling)	3D printing (direct - print)	3D printing (indirect - silicone)
Preparation of CAM design for tooling	required: e.g. radii, no undercuts (!)	avoid steep overhangs, undercuts possible for silicone molds	
Surface quality	smooth	rough – smooth (depending on layer height and post processing)	
Time from CAD model to first part	1-3 weeks	2-3 days	2-5 days
Mold price	300 – 1000 €	< 10 €	< 30 €
Infiltration cycles	1000 and more	< 5	< 20
Application	large series	prototypes	mini series

Conclusion

- Based on 3D printing, different methods have been developed suitable for the production of prototypes and small series
- Even high quality TFP prototypes can be produced by making use of smoothing options (acetone smoothing of ABS prints and / or clear coat)
- Only low cost equipment needed (FDM printer, vacuum pump, optionally oven)

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Thank you for your attention