COMPOSITE ACTUATORS MADE OF SHAPE MEMORY ALLOY WIRES AND MULTI-MATRIX FIBER REINFORCED PLASTICS

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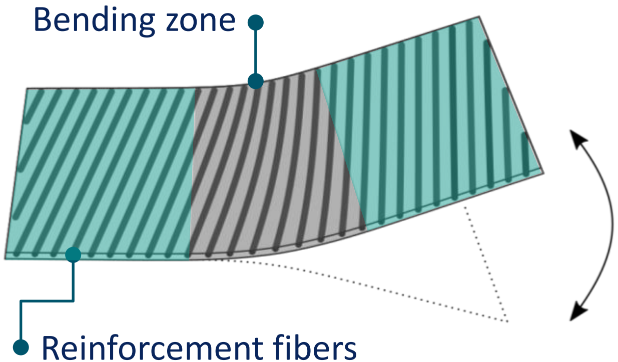
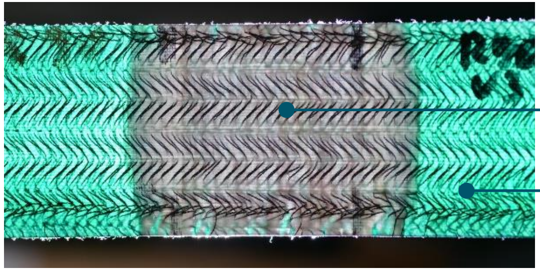
1. Introduction and Motivation

Multi-matrix fiber reinforced plastics (MM-FRP)



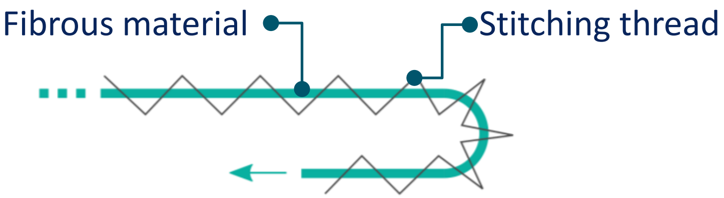


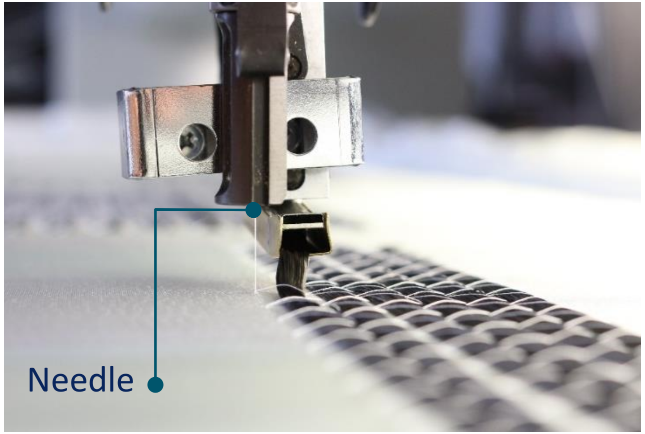
- Composite structures with locally defined bending zones
- Continuous fiber-reinforcement possible
- 2-step vacuum assisted infiltration process (VAP) for the realization of MM-FRP [1]

[1] S. Konze, A. Spickenheuer, F. Conrad, J. Herold, M. Wildemann, J. Schirmer & M. Stommel “Application of additive manufacturing for the production of multi matrix composites”, Proceedings of SAMPE EUROPE Conference and Exhibition, Baden/Zürich, 2021

1. Introduction and Motivation

Tailored fiber placement (TFP)



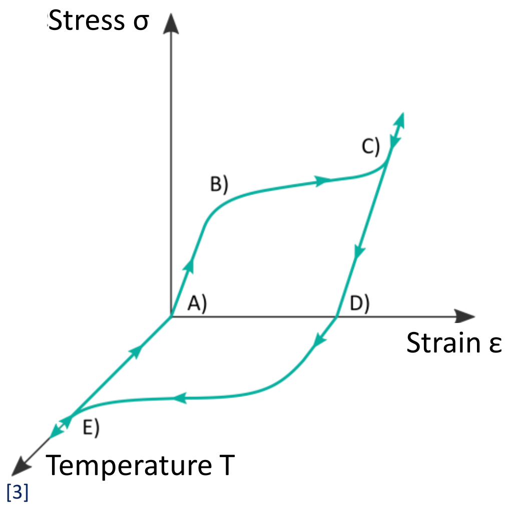


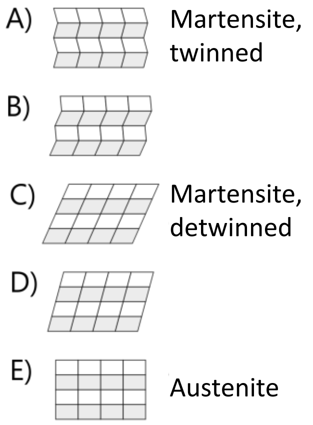
- Variable-axial fixating of fibrous material via embroidery onto base material [2]
- Suitable for wires, also shape-memory alloy wires

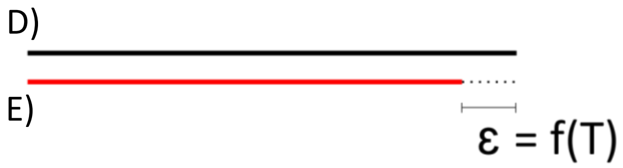
[2] P. Mattheij, K. Gliesche & D. Feltin "Tailored fiber placement - mechanical properties and applications." Journal of Reinforced Plastics and Composites 17(9) (1998): 774–786.

1. Introduction and Motivation

Shape-memory alloy (SMA)





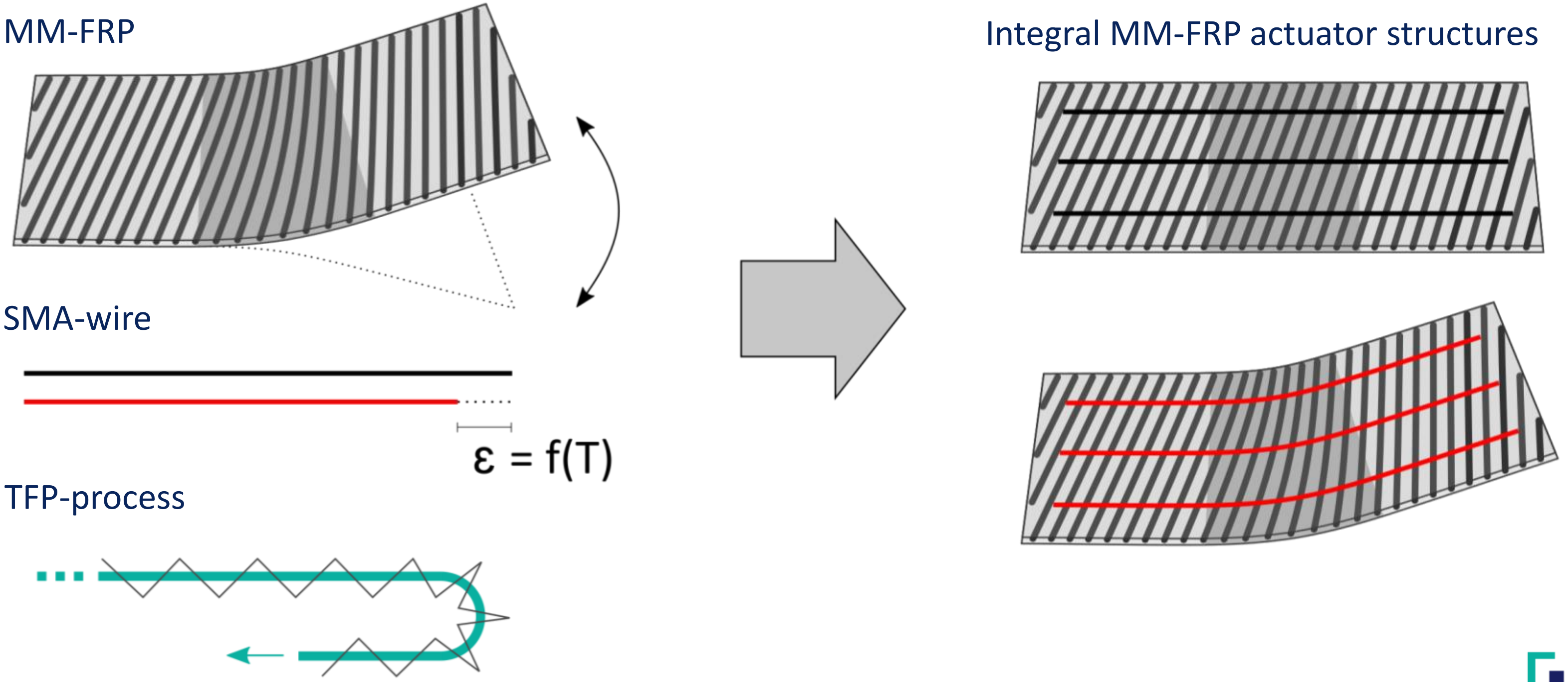


- Smart material with temperature-dependent phase transformation
- Reversible transformation
- Wires as semi finished product with contraction upon heating
- Heating possible via electric current

[3] Figure after S. Langbein, A. Czechowicz “Konstruktionspraxis Formgedächtnistechnik”, Springer Vieweg, 2013

1. Introduction and Motivation

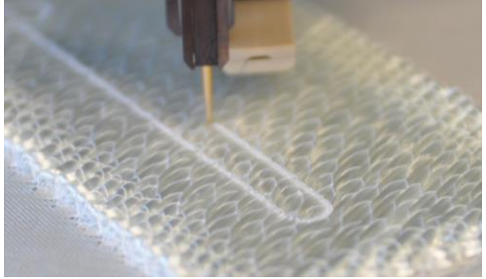
Actuatable composite structures with locally defined bending zones

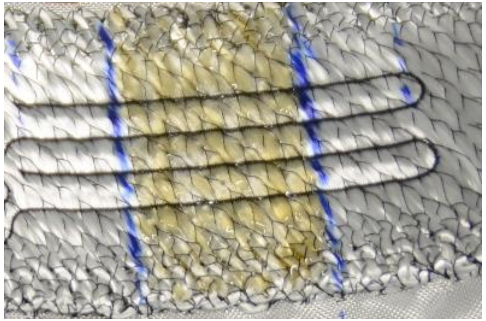


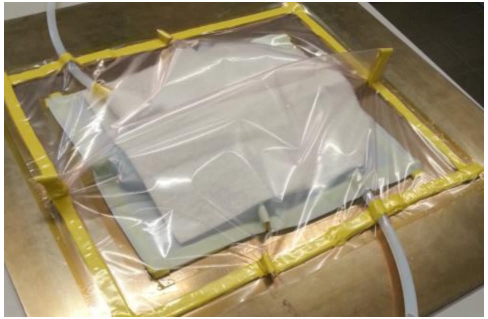
2. Production of Integral MM-FRP Actuator Structures

Manufacturing process

1. Embroidery of pre-strained SMA-wire onto preform
2. Preparation of preform for matrix application
3. Application of PU-matrix in target area
4. Setup of VAP-mold
5. Curing of PU-Matrix
6. Infiltration and curing of Epoxy resign
7. Tempering of composite
8. De-molding, cutting, finishing







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Conflicting temperatures:

Transition temperature (austenite-start) of SMA below processing and curing temperature of PU-matrix

→ Loss of actuator capacity possible

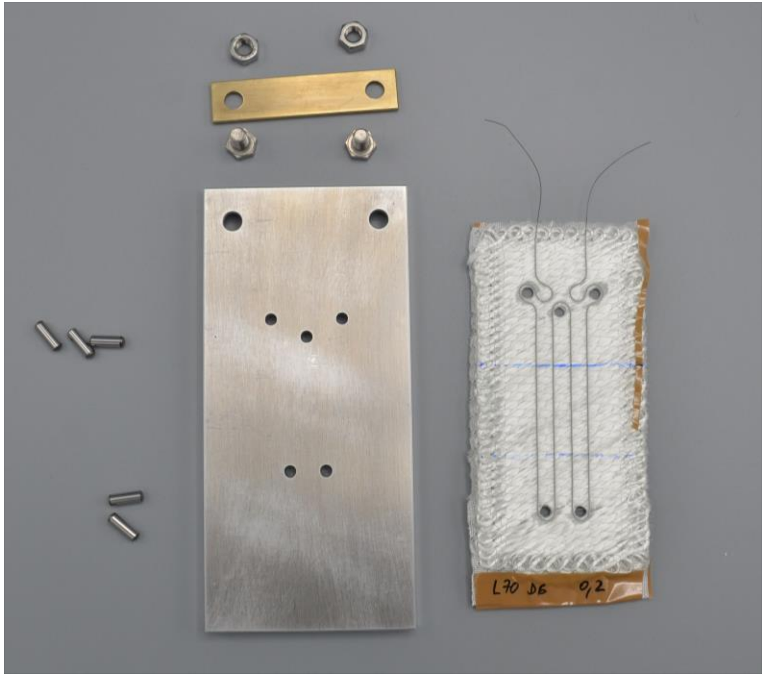
Blocking of SMA-wire contraction:

→ Fixation via embroidery (TFP)

→ Fixation by means of tools

2. Production of Integral MM-FRP Actuator Structures

Consolidation tool



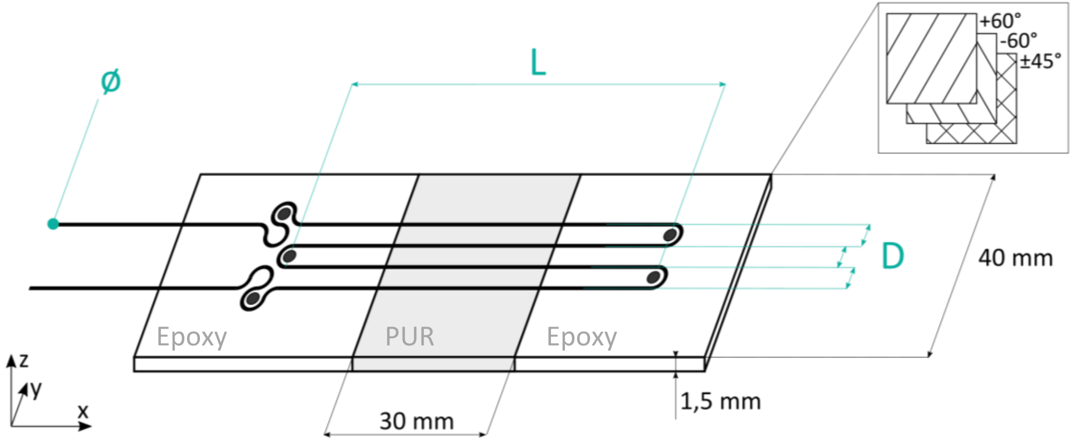
- Hybrid approach for fixation of the wire

→ Fixation by embroidery
→ Inexpensive tool (plates, pins, screws)
→ Easy demolding
→ Easy to clean and reuse

3. Experimental Investigation

Design of test specimen

- Glass fiber preforms
- PU-zone in the center of wire path (actuation zone)
- SMA-wire in meandering pattern
- Variation of design parameters



Design parameters

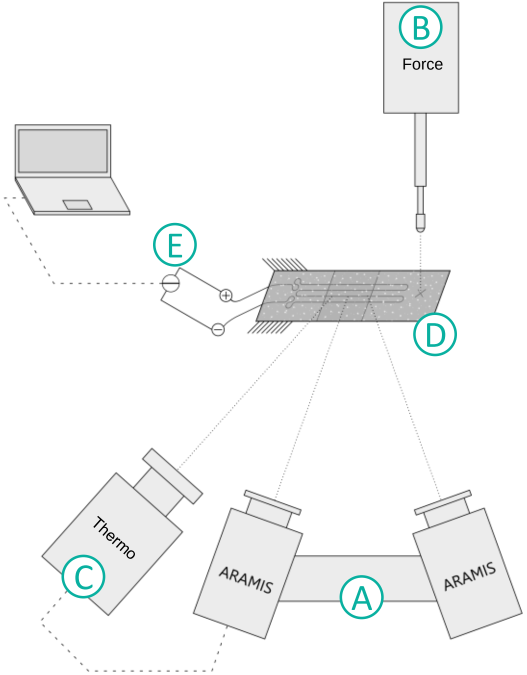
Wire length	L:	45/70/90 mm
Wire distance	D:	4/6/8 mm
Wire diameter	Ø:	100/200/310 µm

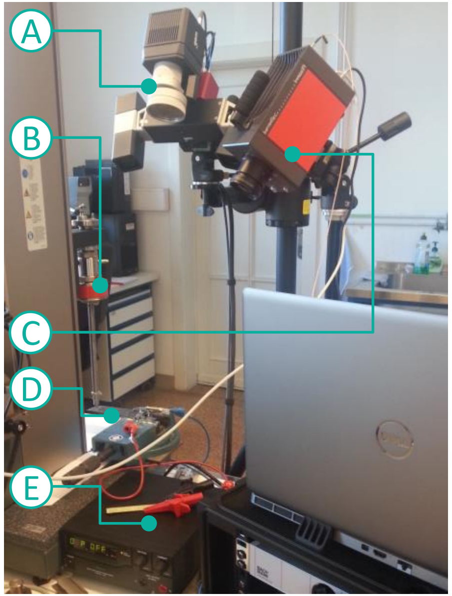
3. Experimental Investigation

Experimental setup

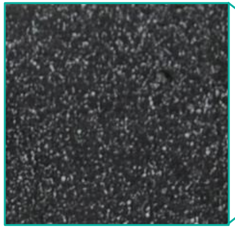
→ **Deformation measurement** (angular) without external force (A)

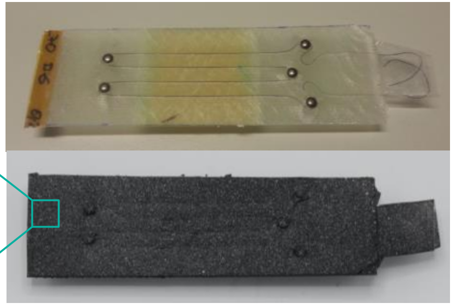
→ **Force measurement** with blocked deformation (B)





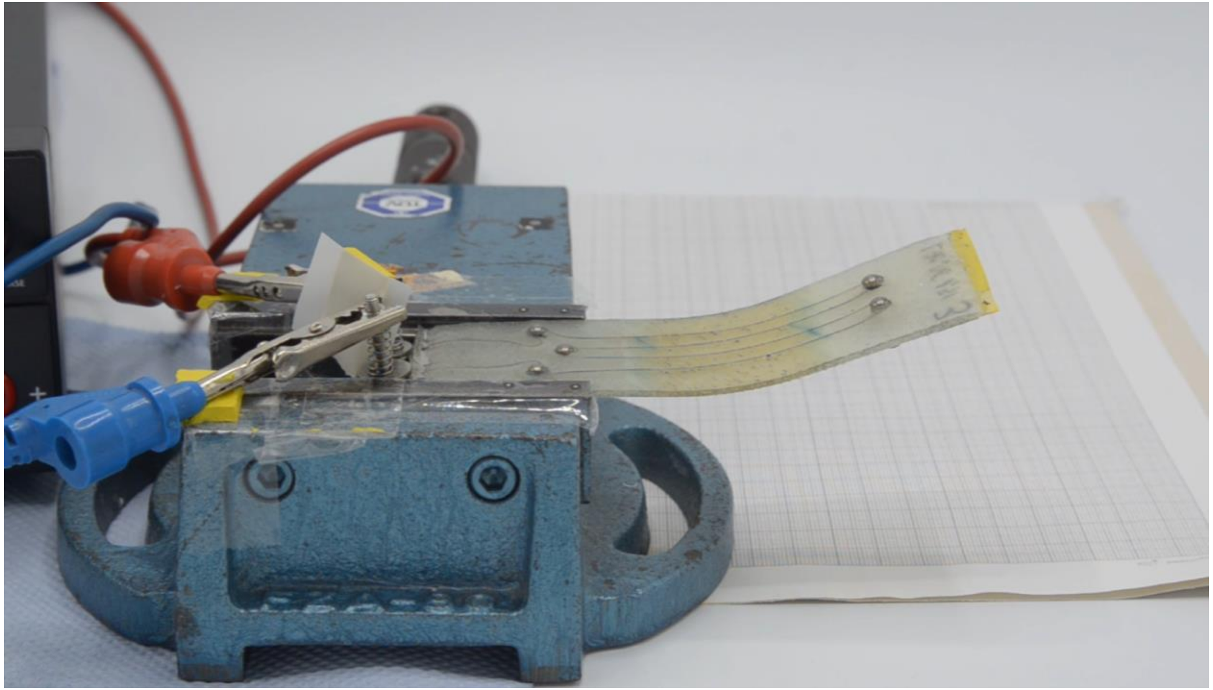
A	System for digital image correlation (ARAMIS)
B	Load cell
C	Thermographic camera
D	Specimen
E	Power source





4. Results

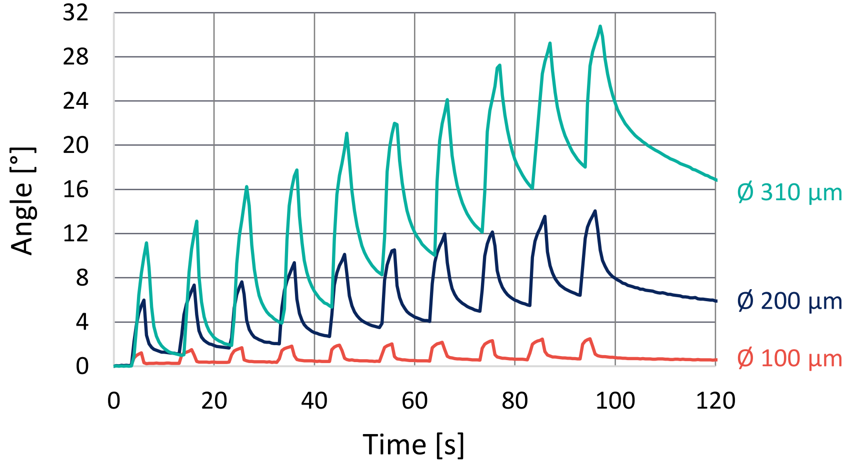
Activated specimen



4. Results

Wire diameter

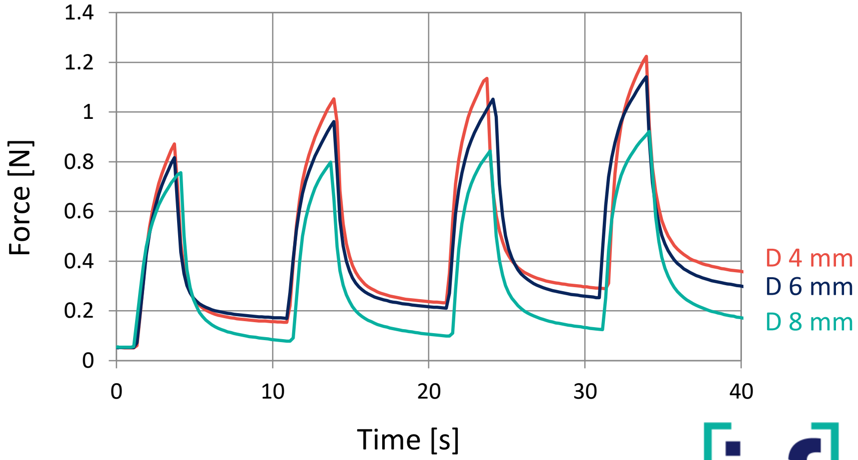
- Deformation angle increases for bigger SMA-wire diameters



Wire distance

- Increased blocking force for smaller wire distance

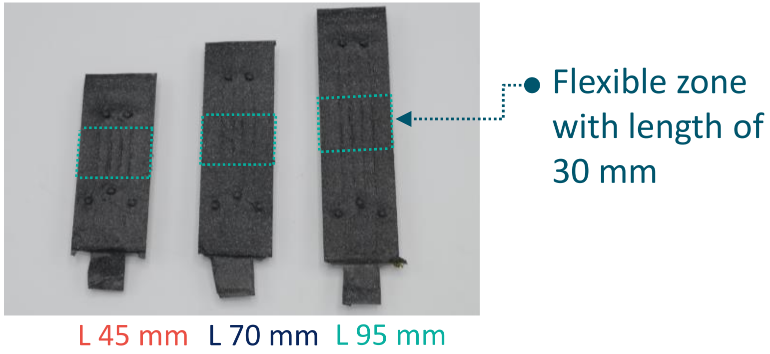
  → Concentrated heat influx effects the austenite transformation of SMA

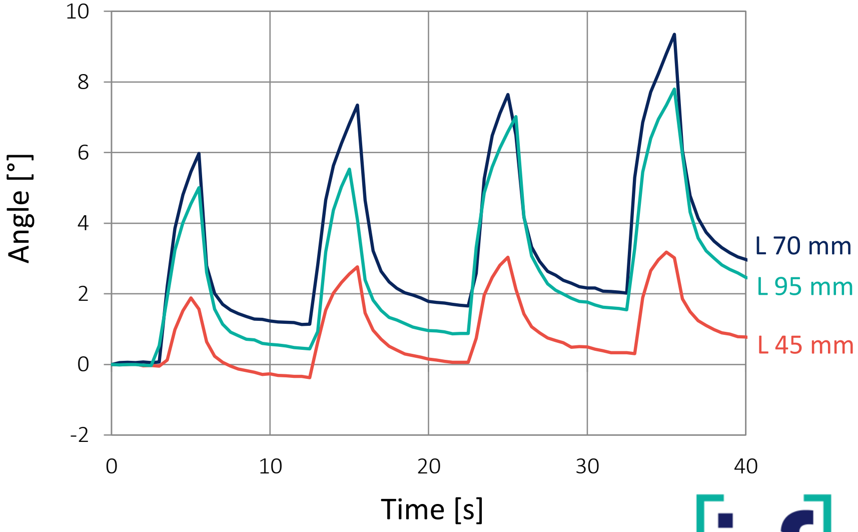


4. Results

Wire length

- Reduction of blocking force for smaller length
  → Possible loss of pre-strain
- No increase of blocking force for bigger length
  → Flexible bending zone (constant length) of significant influence





5. Conclusion

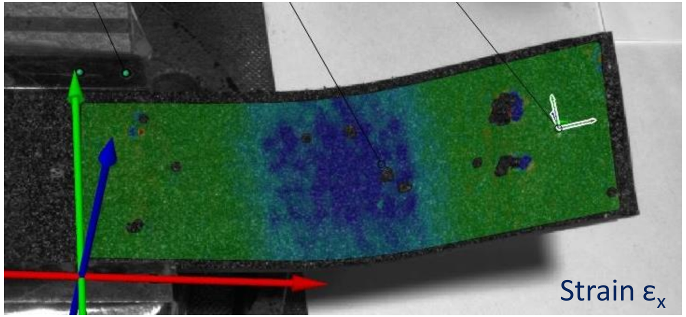
Integrated MM-FRP actuator structures made by TFP

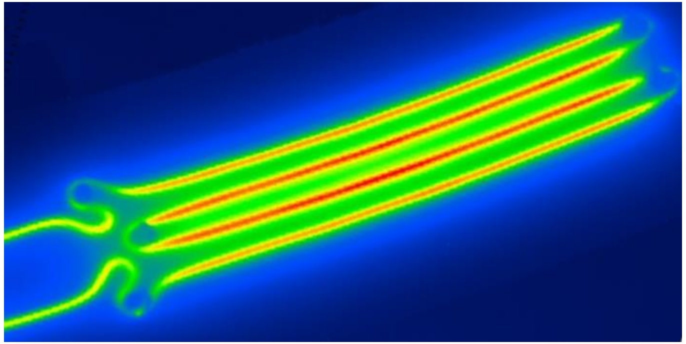
- All specimens working
- Bending mainly in the area of the PU-matrix

→ Reliable manufacturing method for smart composites with locally defined bending zones

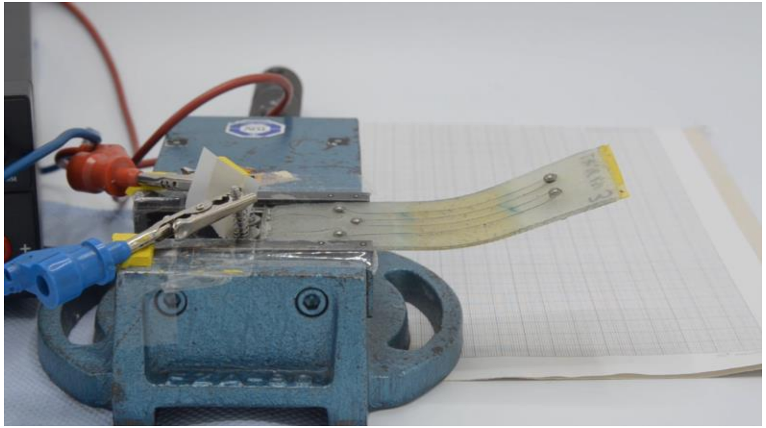
→ Suitable for individualized and automated production via TFPprint [4]

→ Actuator structures in robotics, valves, clean rooms, etc.





[4] S. Konze et al. "Introduction of an additive manufacturing process for multi-matrix fiber reinforced composites", SAMPE Conference Proceedings. Seattle, WA, April 17 -20, 2023. Society for the Advancement of Material and Process Engineering – North America. pp. 437-446



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