North American Pultrusion Conference

From Small Colorful Elements to the Final Profile: A Simulation of the Pultrusion Process

Dipl.-Ing. David Löpitz

Fraunhofer Institute for Machine Tools and Forming Technology IWU

ACMA American Composites Manufacturers Association | EPTA

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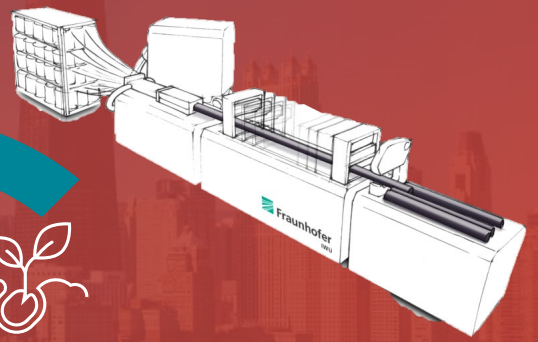
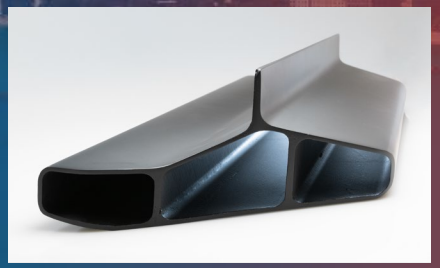
… about the implementation …



From the idea …



… to the finished product.

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Simulation in a 70 years old process - Why?

Advantages of simulation

- Reduction of development times (from the idea to the finished profile)
- Reduction of time-consuming trials (end with the “Trial End Error”-method)
- Increase of the economic efficiency (optimized process parameters)

Challenge of simulation

- Building up know-how
- Qualification of new or customized fiber/matrix systems

Source: Online Consulting AG

Variation of the pultrusion parameters

„fix“ parameters

Matrix

Typ
(UP; VE; EP etc.)

Formulation

Fiber

Typ
(Glass, carbon etc.)

Layup
(Roving, fabric etc.)

Tool

Coating

Typ of cross section

Impregnation

High quality profile

„flexible“ parameters

Die temperature

Pull-off speed

(Fiber content)

(Fiber guiding)

“The journey is the reward”

Process quality level

Validation

Design

Reality – Trials

Virtuality – Simulations

Modular & sensored tool

Data generation

for validation

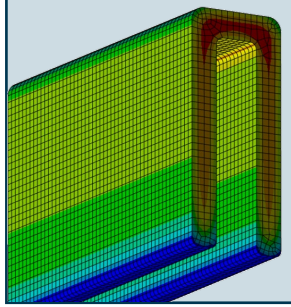
Cure simulation of the profiles

A

More complex U-profile

distortion simulation of the U-profile

B



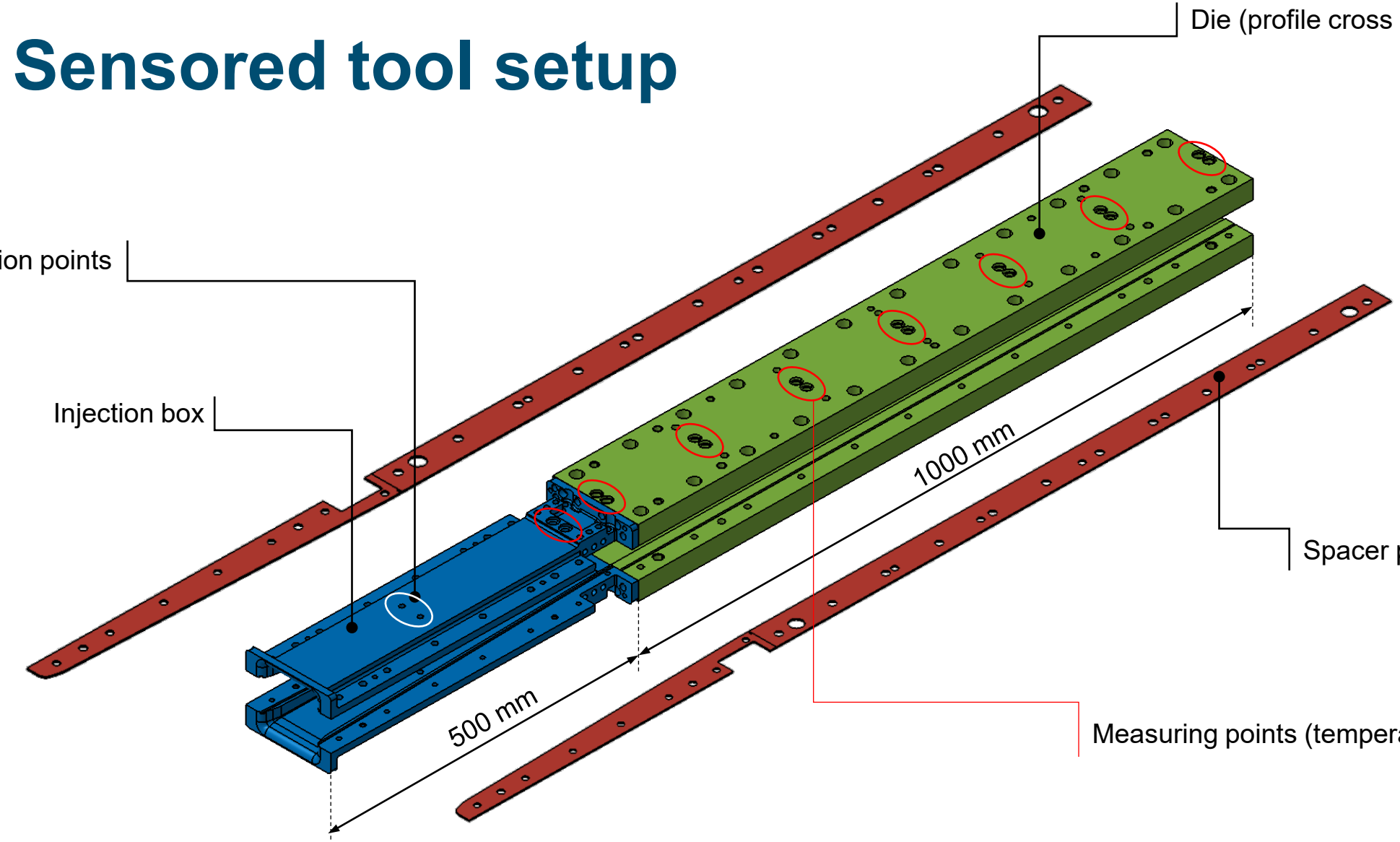
Complex profiles

Process & design simulation of complex profiles

C

Digital twin

Sensored tool setup



A

Integrated measuring systems

At the pultrusion line

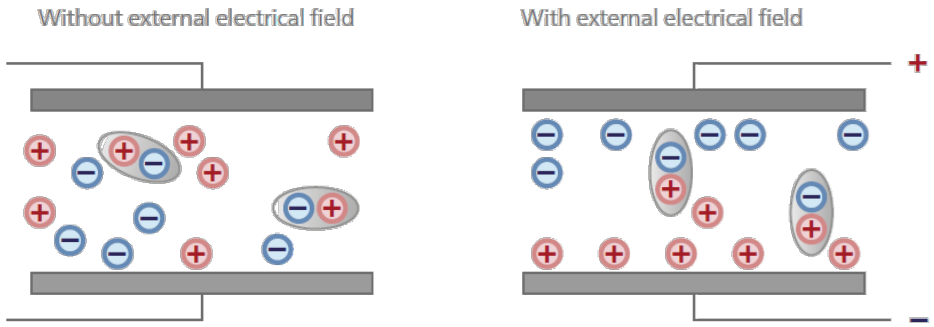
- Temperature
- Pull-off force
- Pull-off speed

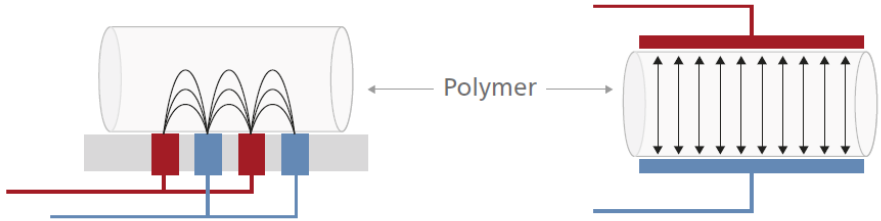
Inside the tool system

- Temperature
- Pressure
- Ion viscosity

Inside the profile

- Temperature
- Ion viscosity





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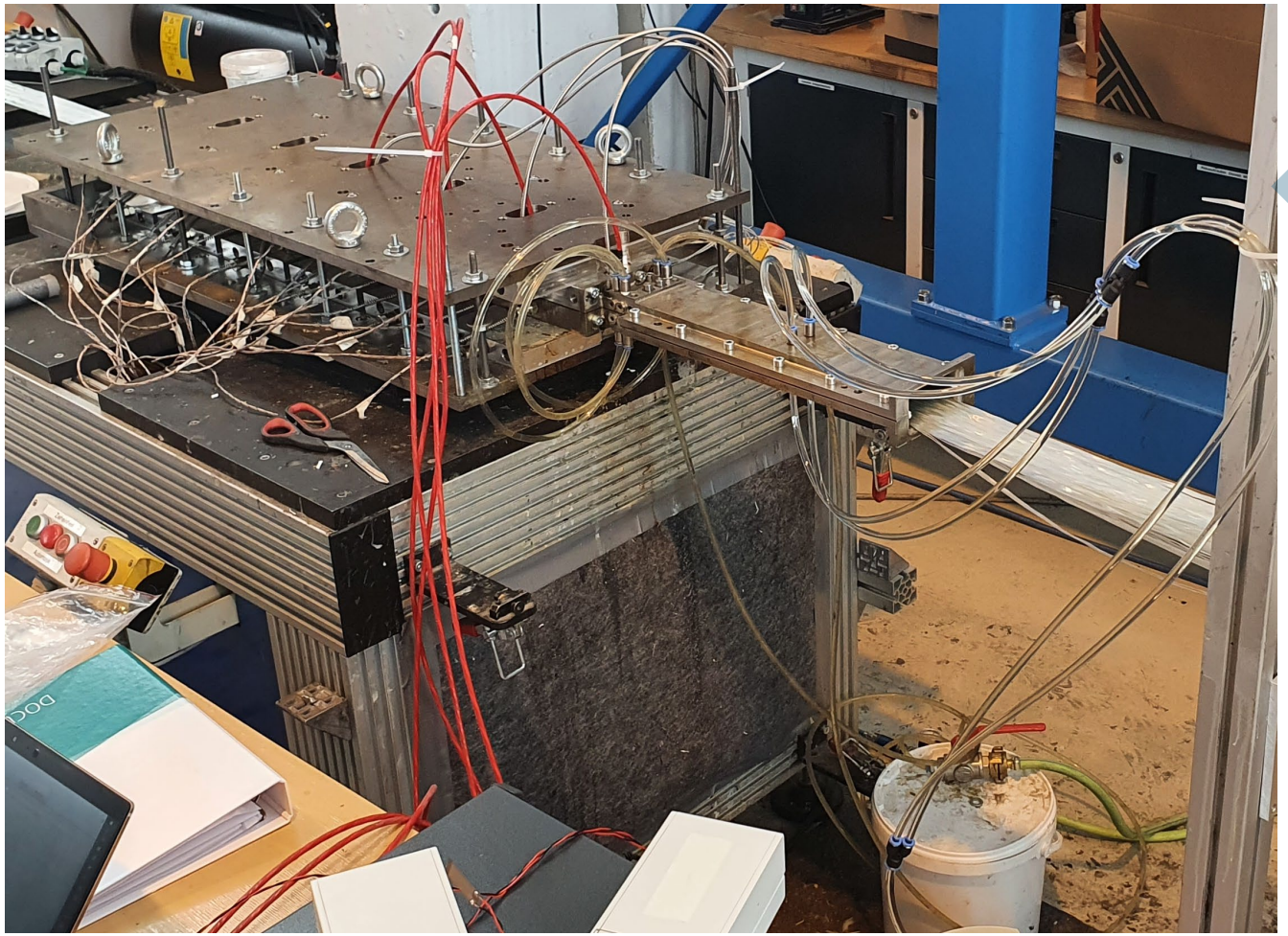
Source: Netzsch.com; DEA 288 Ionic

Selected trial results

- Pressure curves
- DEA curves
- Temperature curves (Validation)



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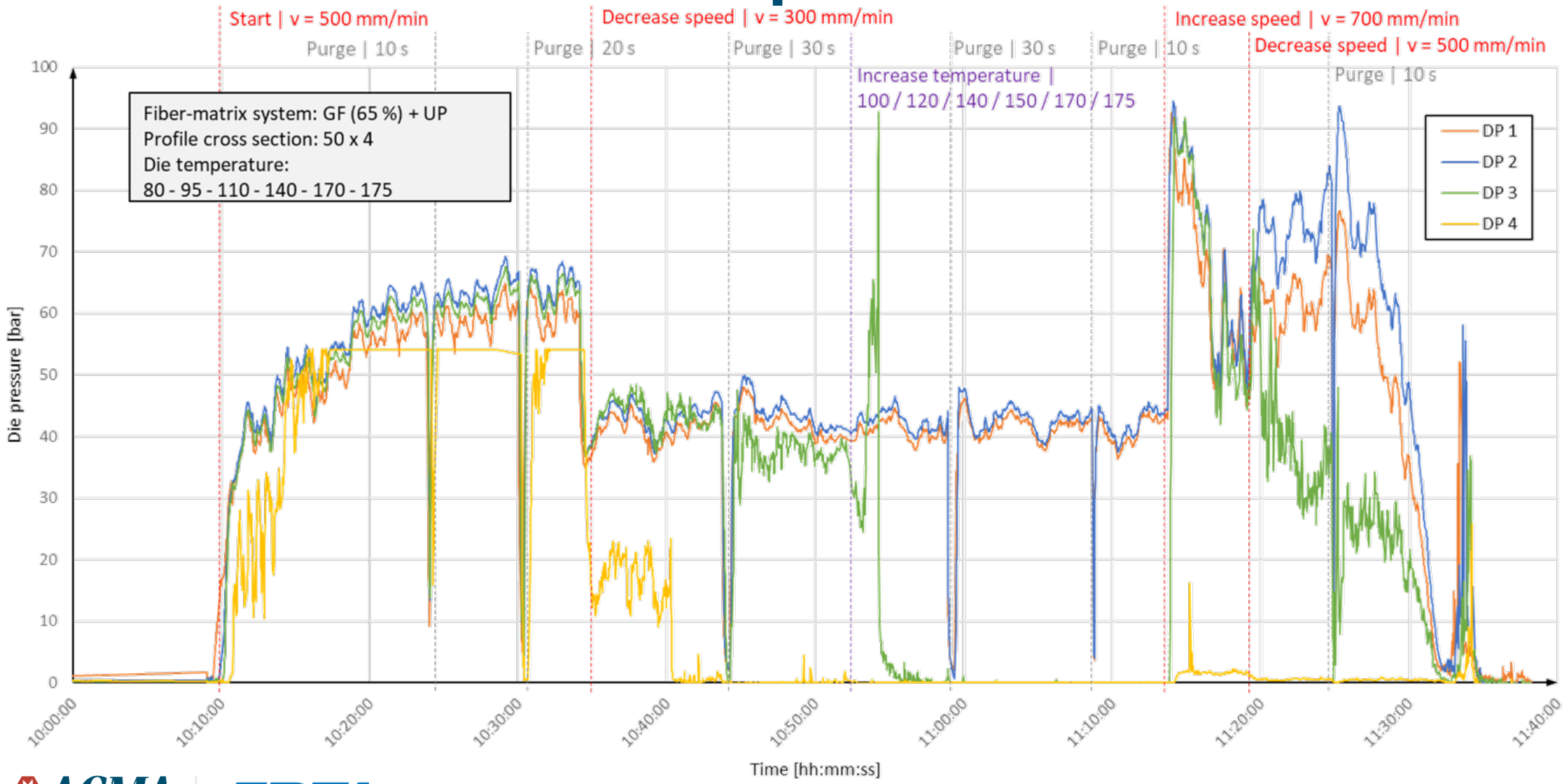
Selected trial results – pressure



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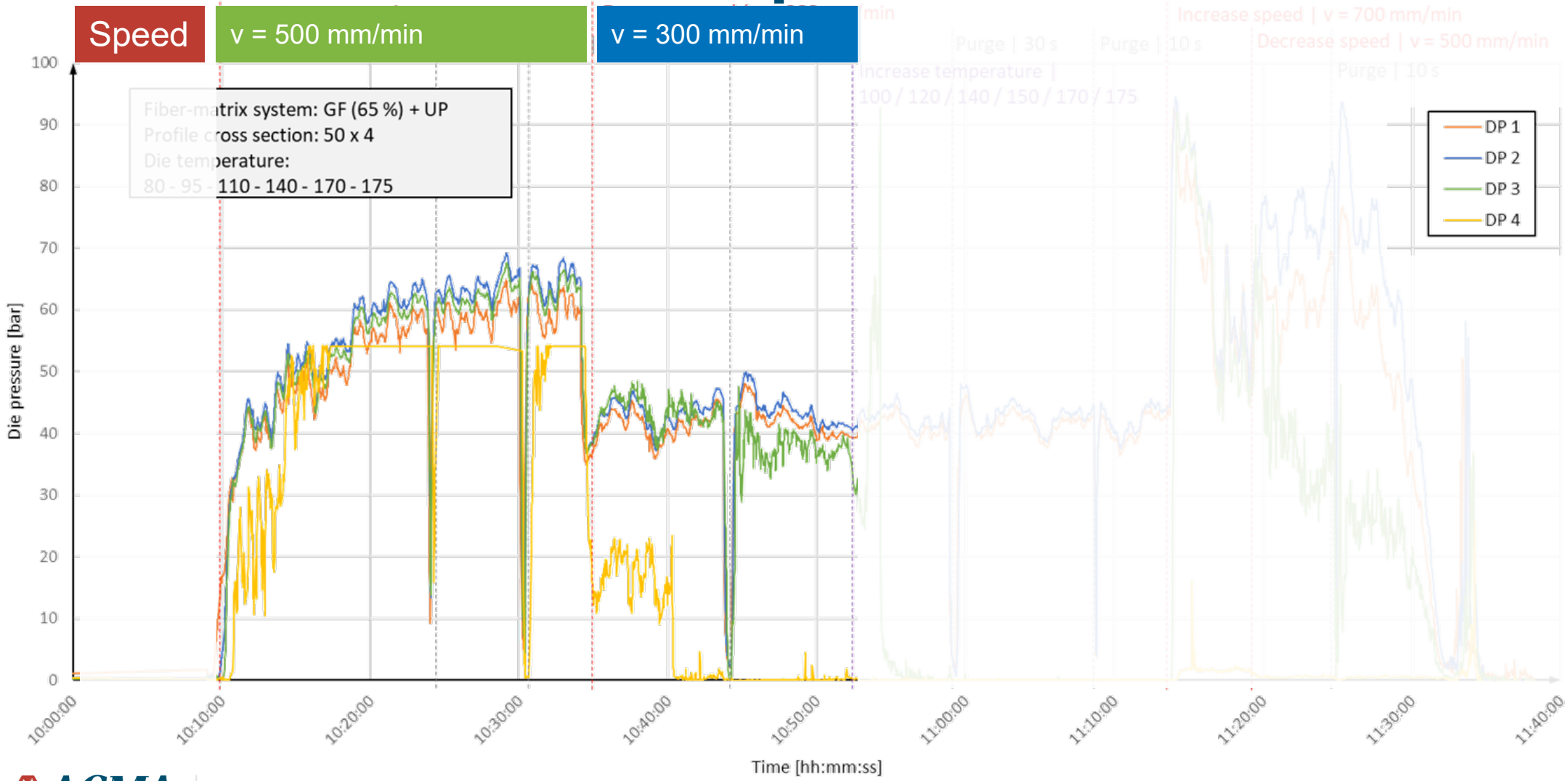
Selected trial results – pressure



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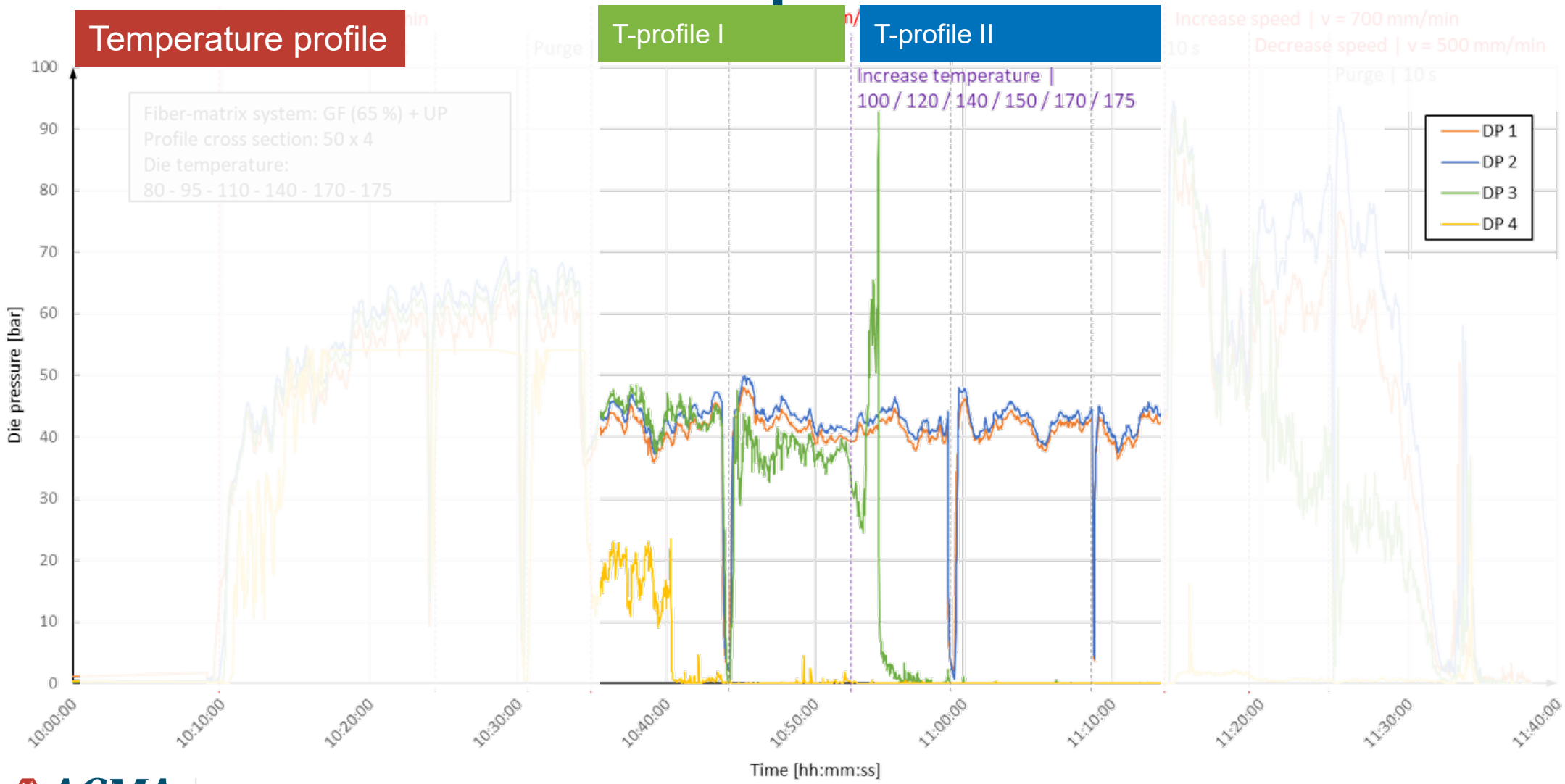
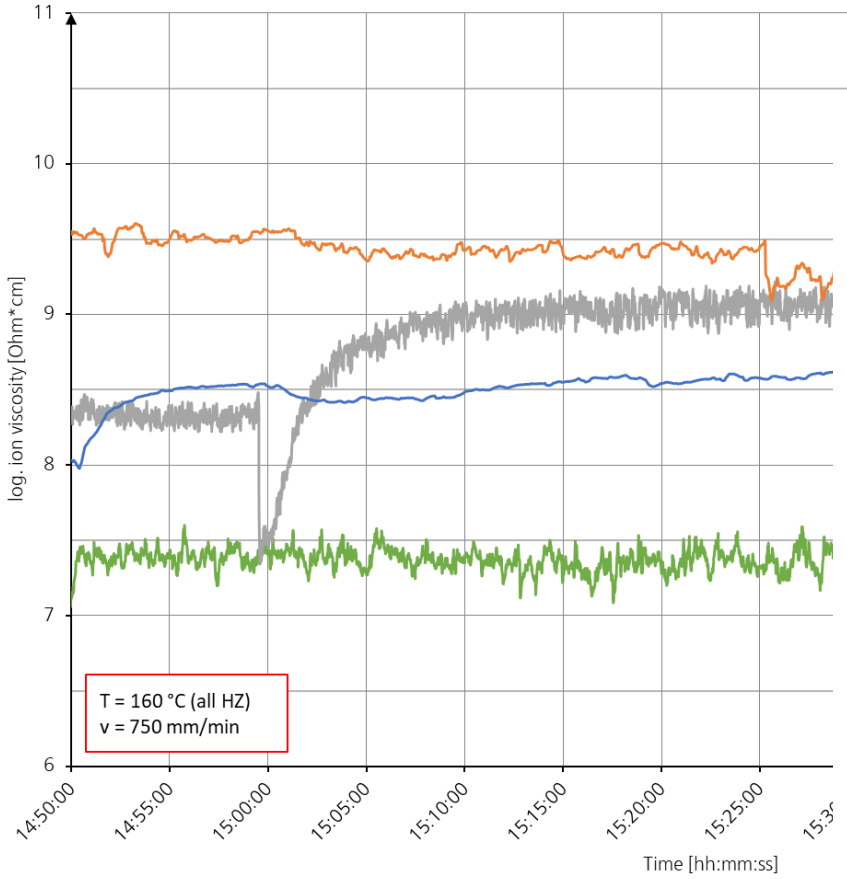
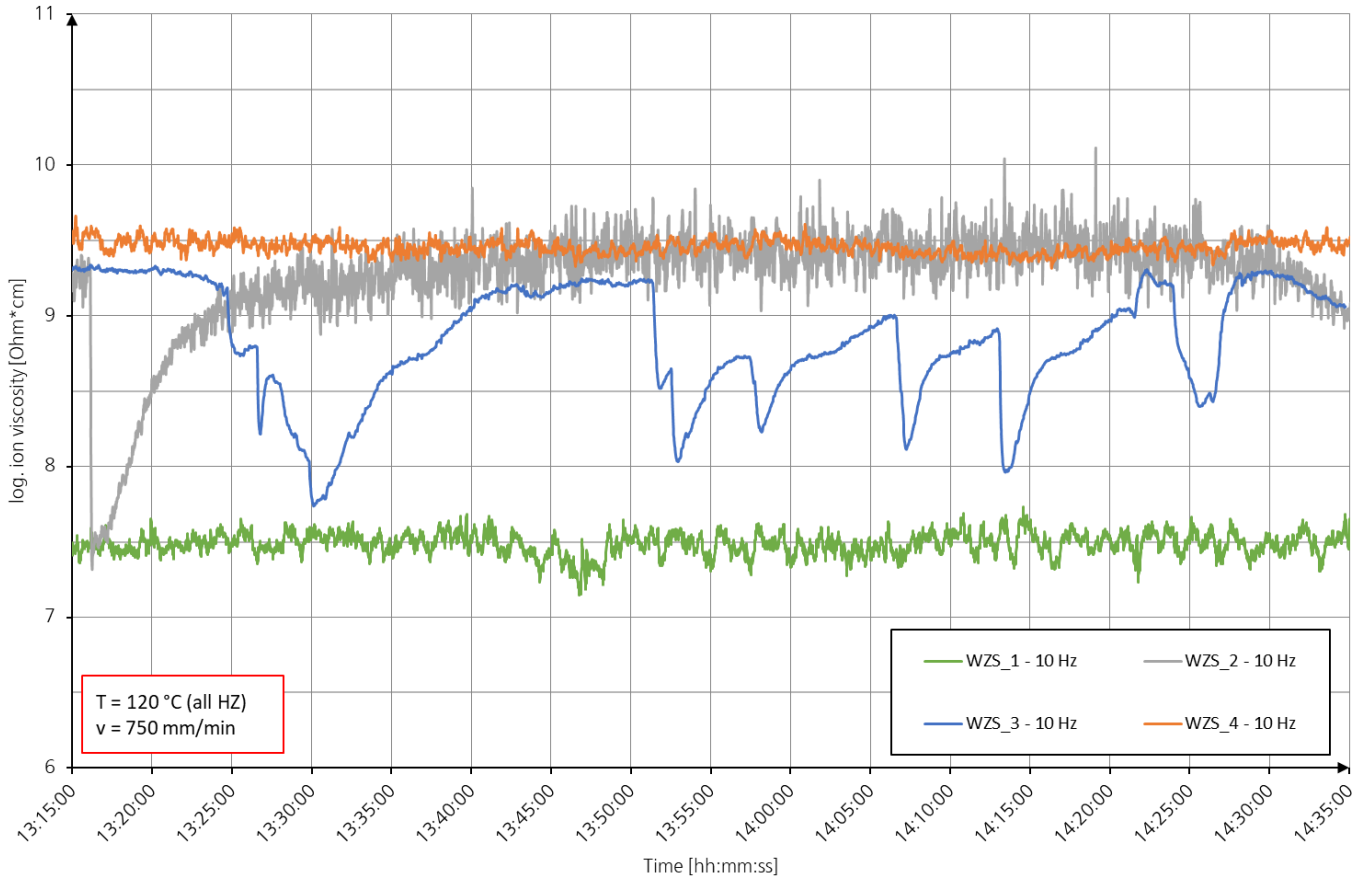
Selected trial results – pressure



A

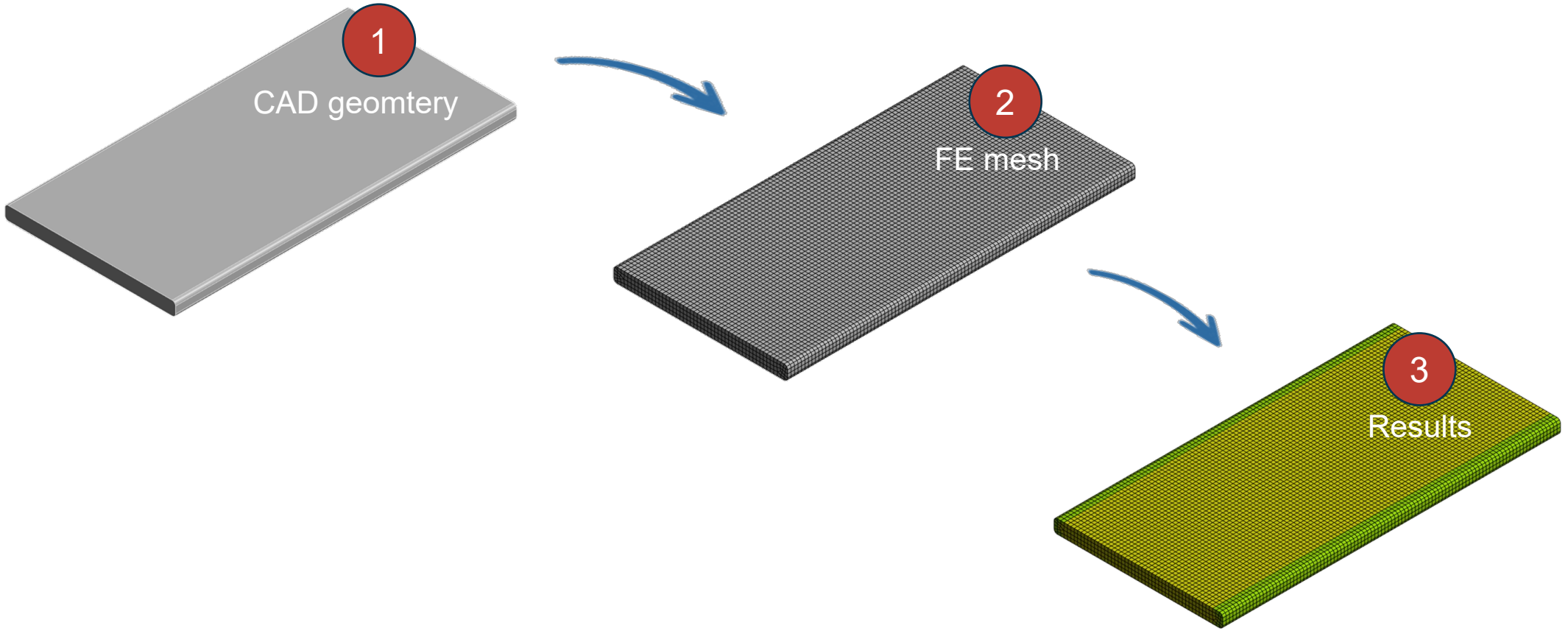
Selected trial results – DEA





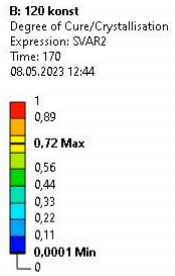
A

Simulation model



A

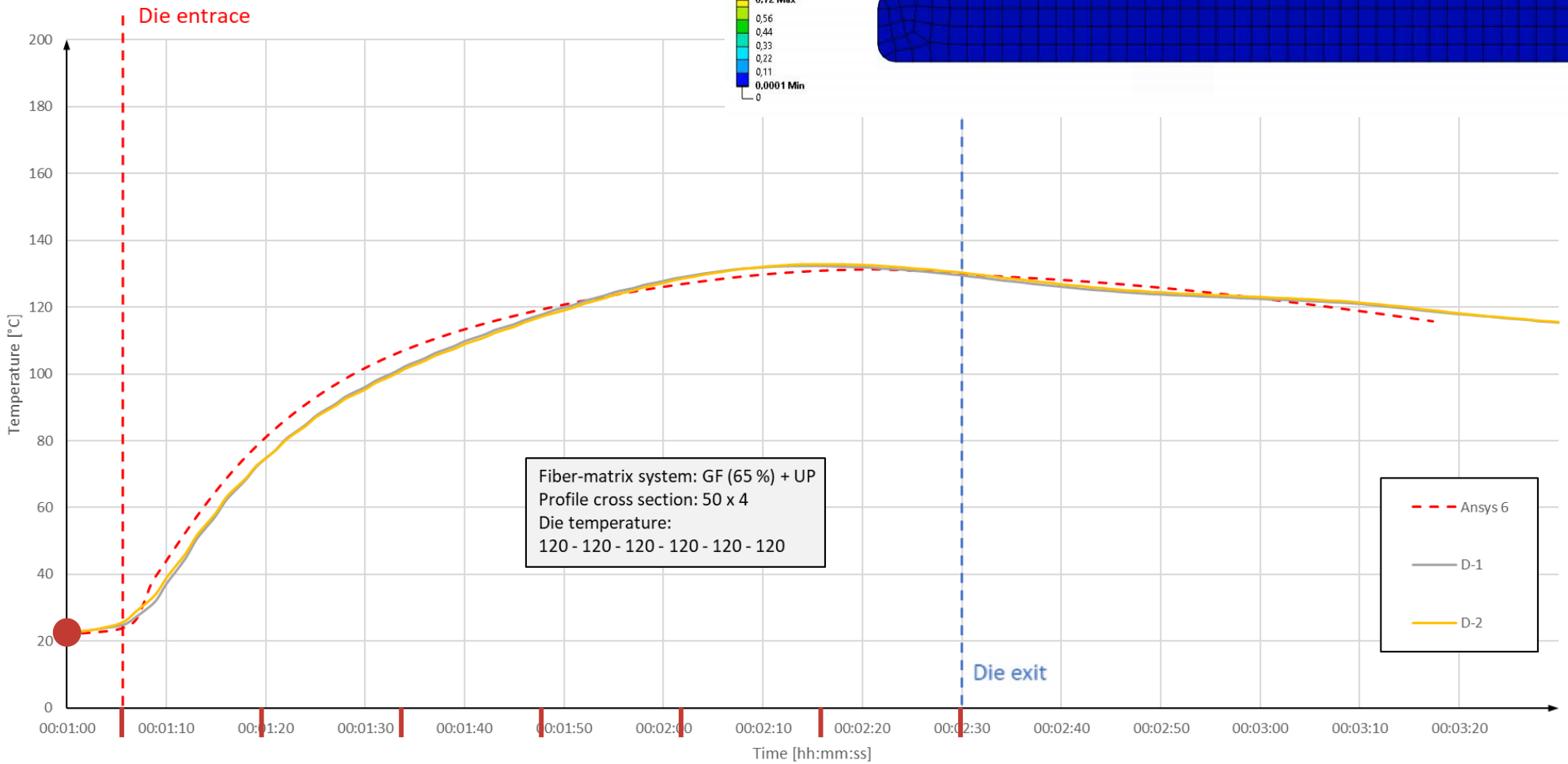
Simulation model



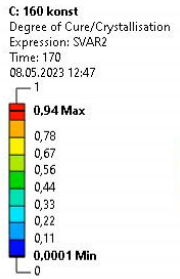
Curing process

Die temperature: const. 120 °C
Pull-off speed: 750 mm/min

A

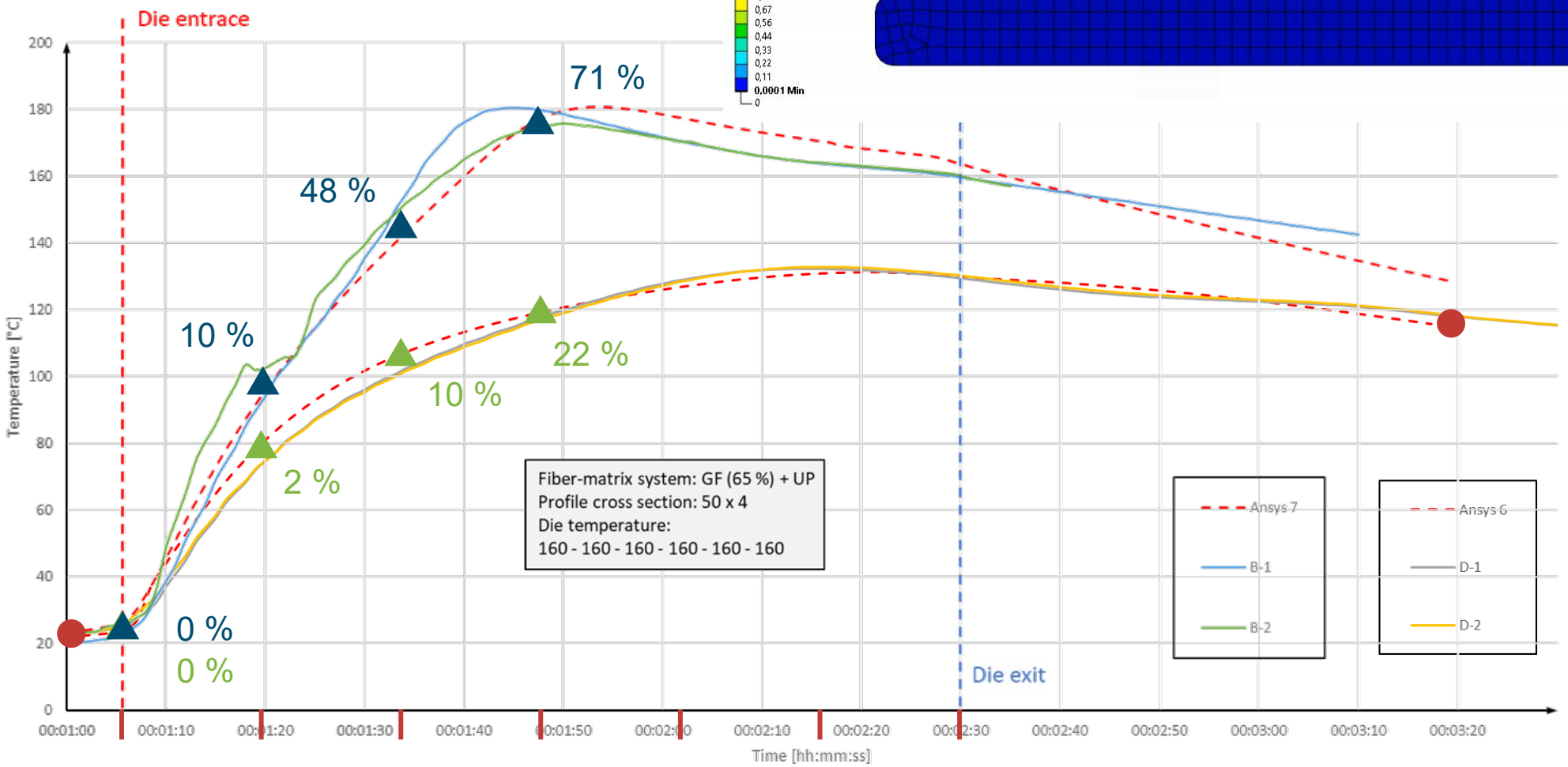


Simulation model



Curing process

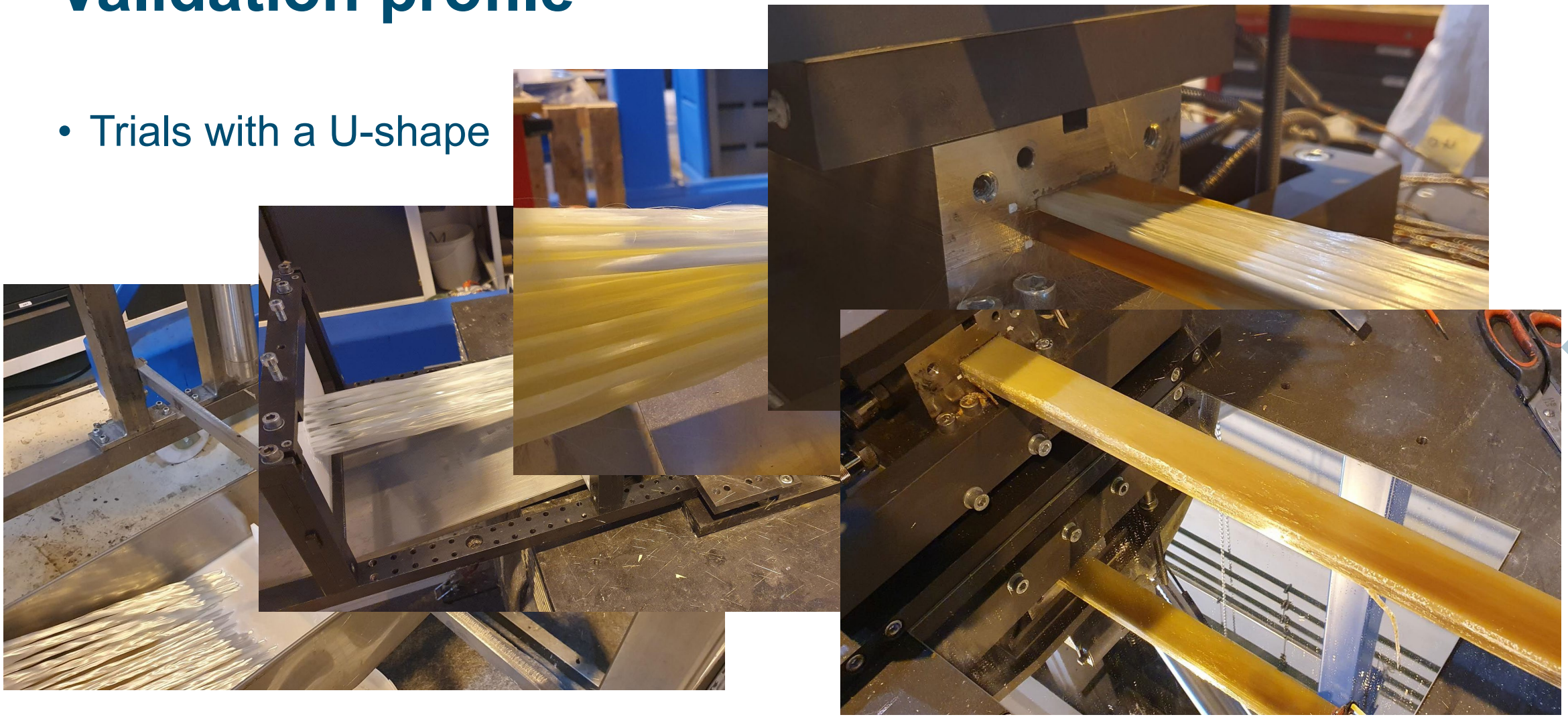
Die temperature: const. 160 °C
Pull-off speed: 750 mm/min



A

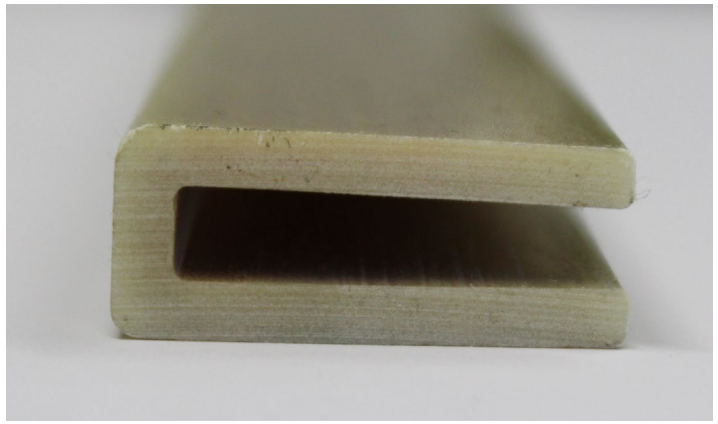
Validation profile

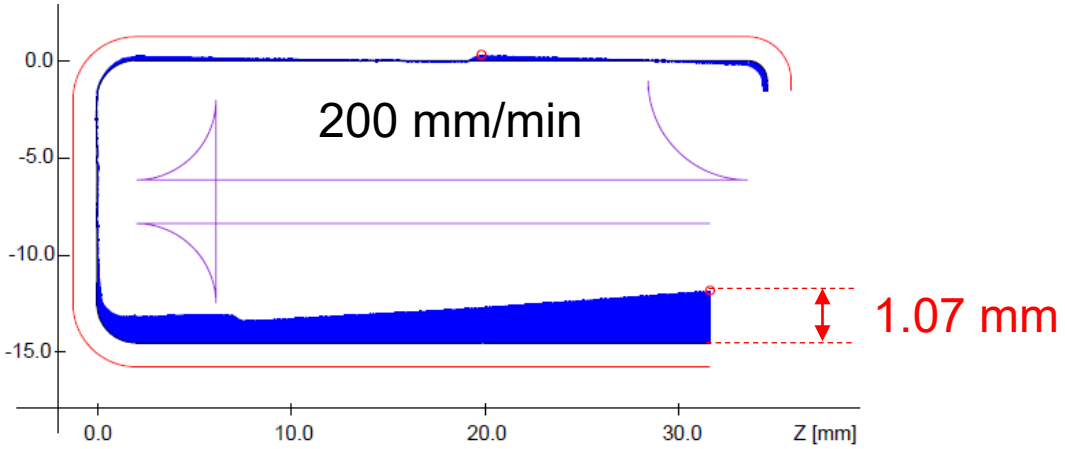
- Trials with a U-shape

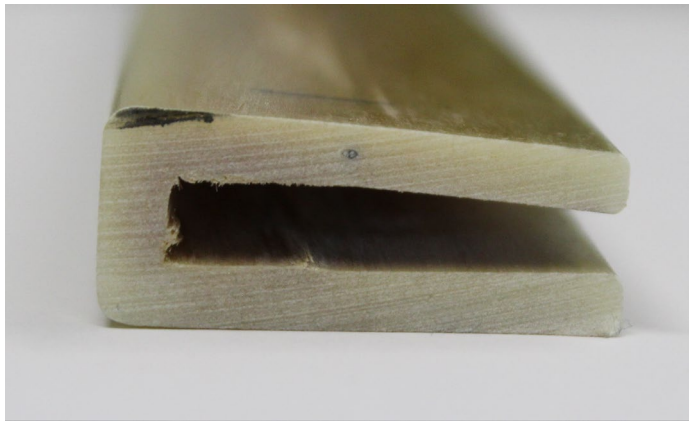


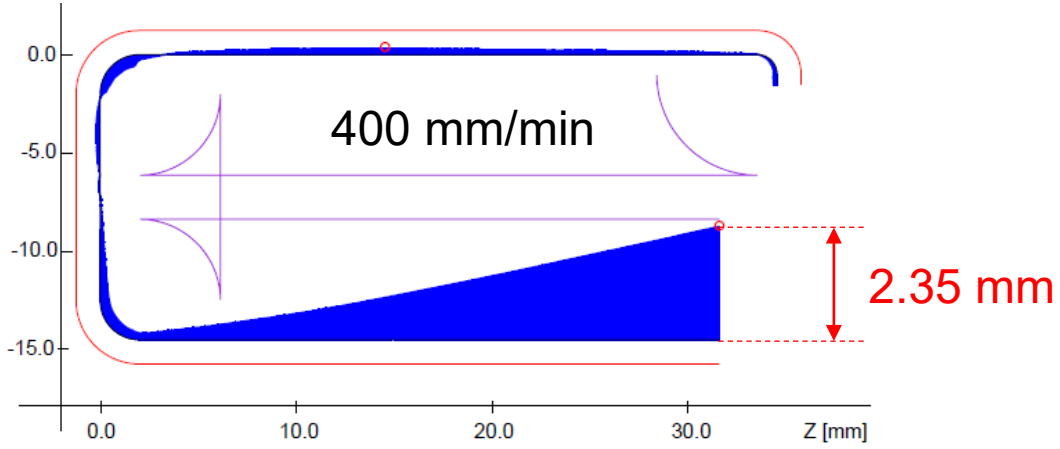
B

Validation profile





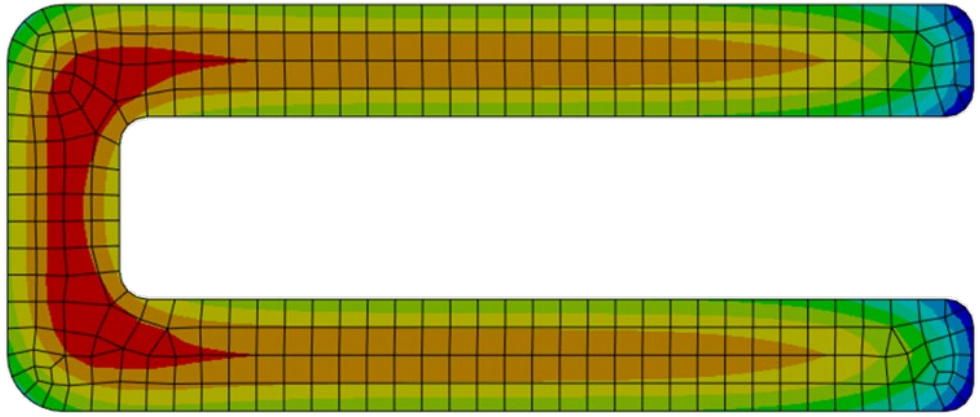




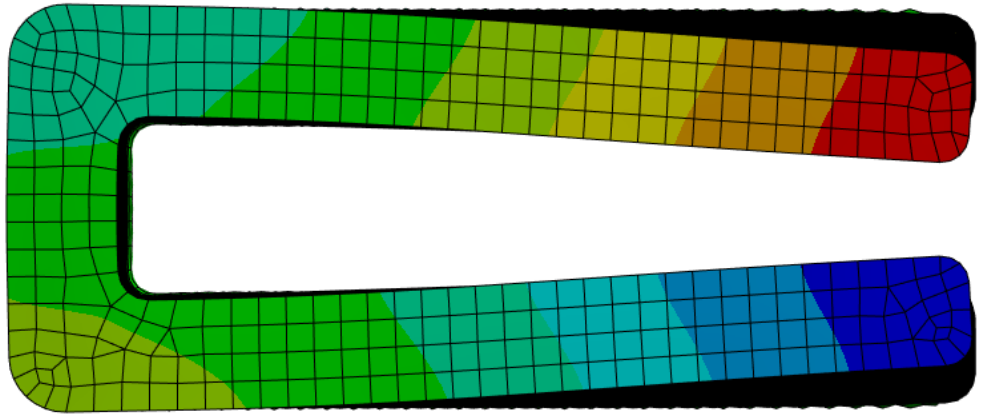
B

Simulation

Curing



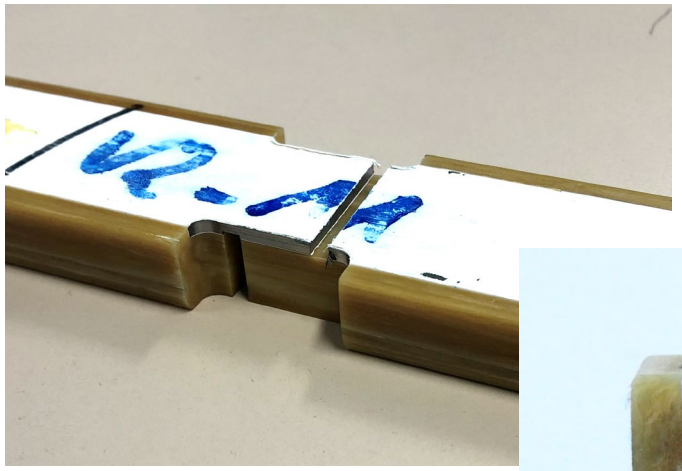
Distortion

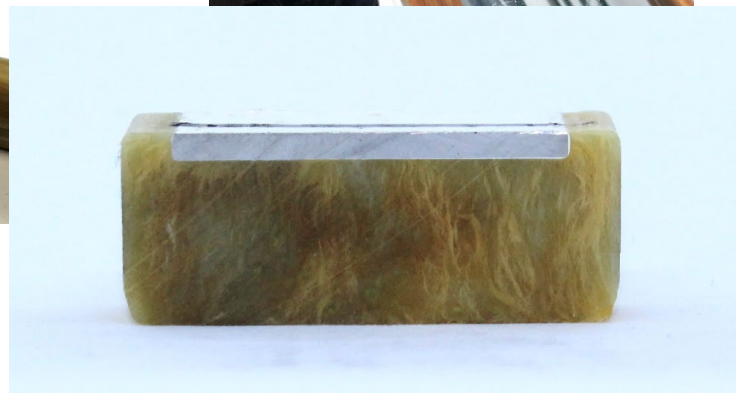


B

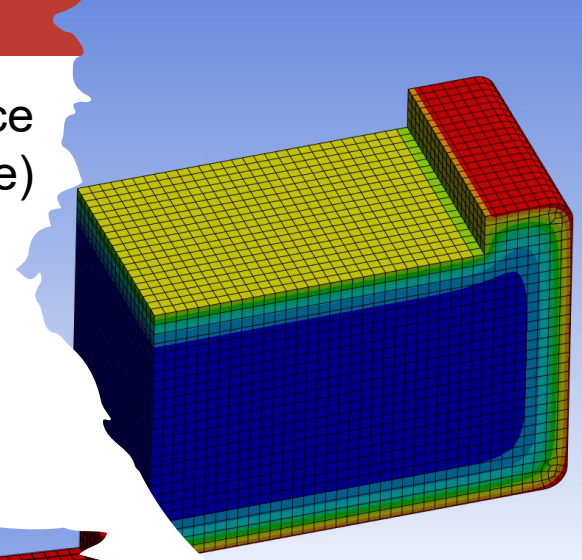
Outlook and application

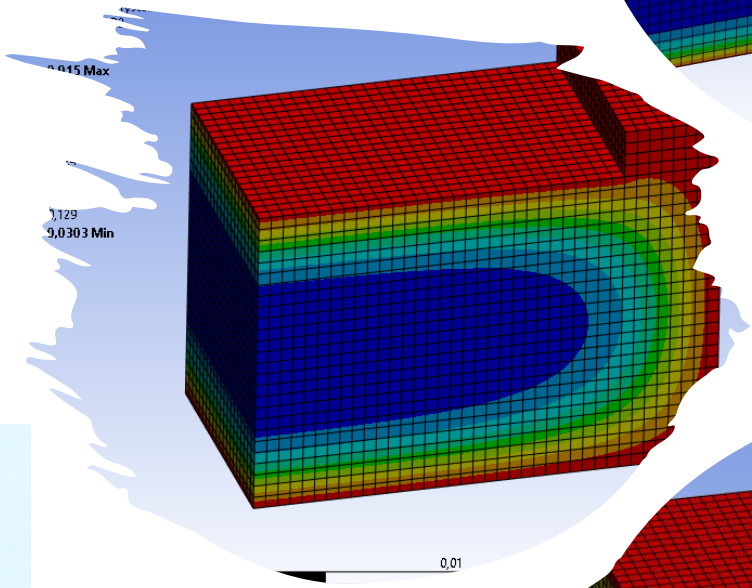
- Hybrid profiles – inline combination of metal sheets and FRP



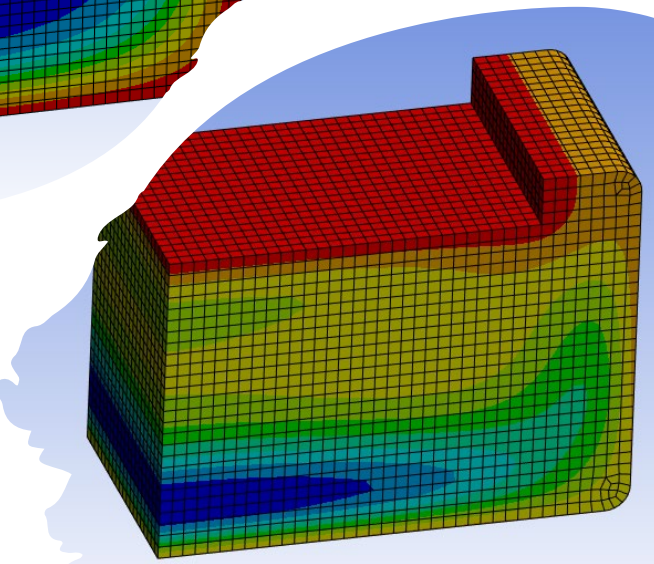


Die entrance
(near 0 % cure)





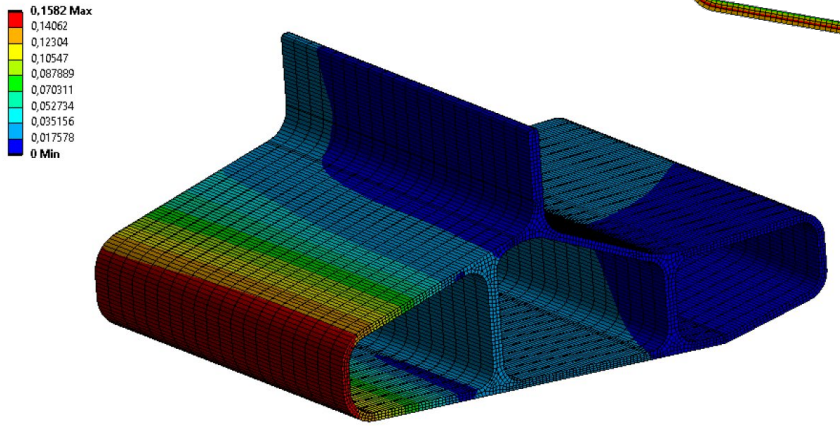
Die exit
(3 – 91 % cure)

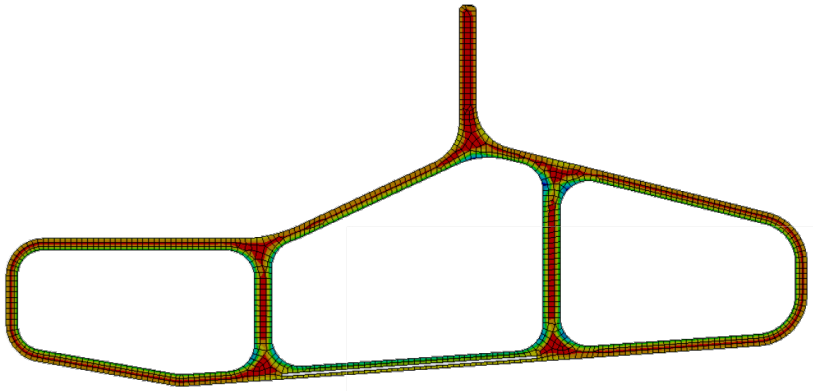


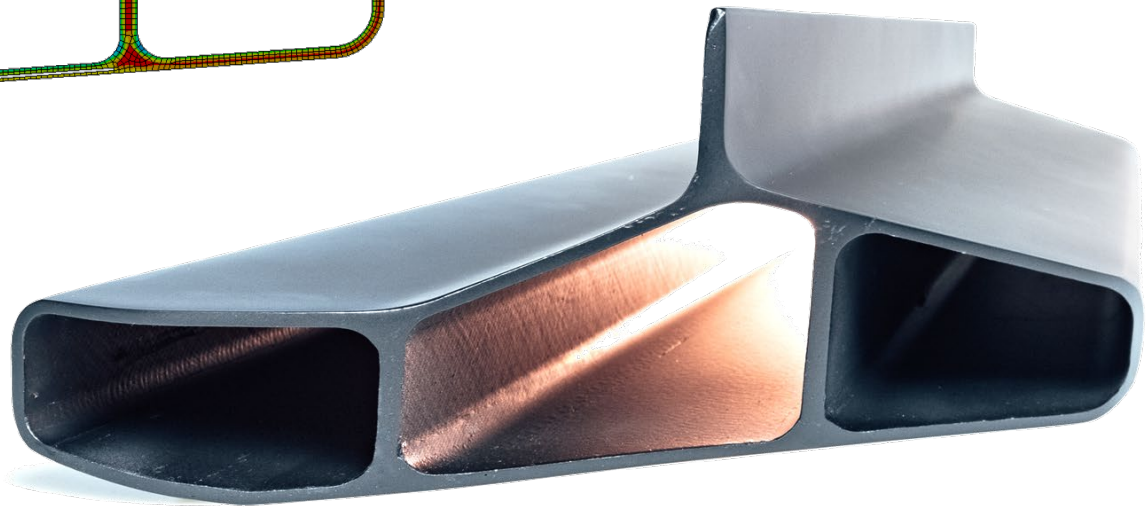
3 m after die exit
(83 – 96 % cure)

Outlook and application

- Complex 3 chamber hollow profile







Summary

- ✓ Sensored die with different cross-sections
  - → Data generation for validation (material & process)
  - → Deeper process understanding
- ✓ Curing simulation (validated)
- ✓ Distortion simulation (validated)

Tool for process design

- Die design
- Optimization of process parameters
- Deeper process understanding for faster adjustments

Fraunhofer IWU

Contact

Dipl.-Ing. David Löpitz
Group Leader Pultrusion

Tel. +49 371 5397-1364
Mobil +49 173 7957 619
David.Loepitz@iwu.fraunhofer.de

www.iwu.fraunhofer.de/pultrusion

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