F11.6.15563 Physics-based DEsign for TAILored Thermoplastic Composites - DETAIL

T.K. Slange

University of Twente (Prof. R. Akkerman)

Industrial partner: ThermoPlastic composites Research Center (TPRC)

materials innovation institute

Nederlandse Organisatie voor Wetenschappelijk Onderzoek

Rapid Manufacturing of a Tailored Spar by AFP and Stamp Forming

Background

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Nederlandse Organisatie
voor Wetenschappelijk Onderzoek

Automated lay-up

Coriolis Composites

AFP

- Automated
- High rate lay-up
- High lay-up flexibility
  - Tailoring
  - (Near) net-shape
- Complex geometries

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- Complex geometries

Quality: In-situ consolidation

- Low rate lay-up, complex geometry
- Full consolidation
  → no post-consolidation

Challenging!

Automated lay-up

Coriolis Composites

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- High rate lay-up
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  - Tailoring
  - (Near) net-shape
- Complex geometries

Quality: In-situ consolidation

- Low rate lay-up, complex geometry
- Full consolidation
  → no post-consolidation

Challenging!

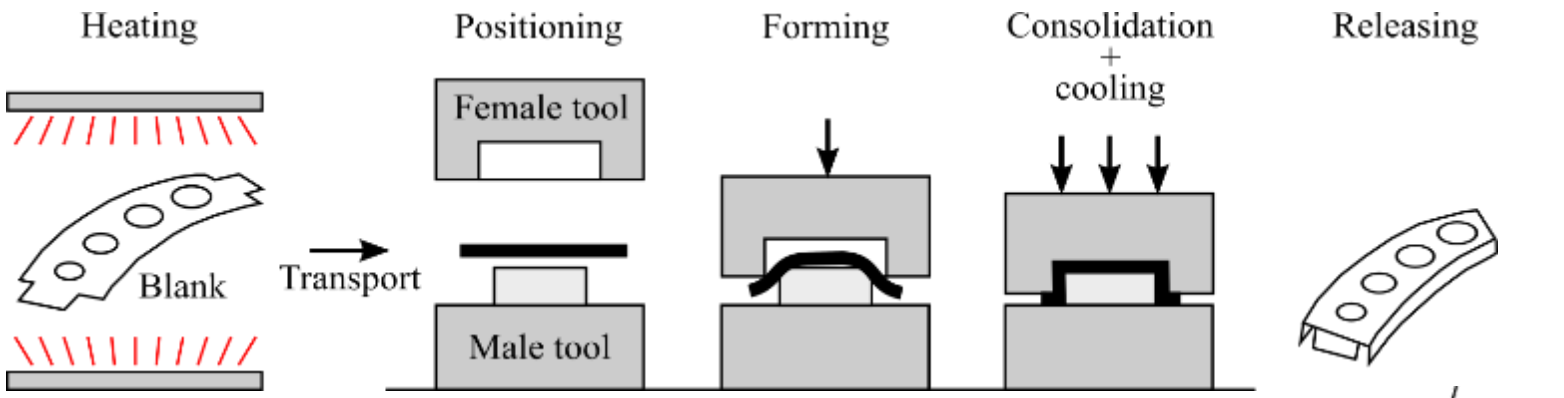
Productivity: Rapid lay-up

- High rate lay-up, simple geometry
- Limited consolidation
  → post-consolidation required

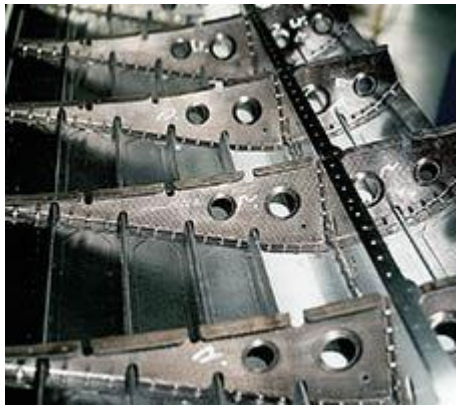
Rapid post-consolidation?

Stamp Forming

- Rapid forming of flat blank into 3D component
- Press/autoclave consolidated blanks of uniform thickness



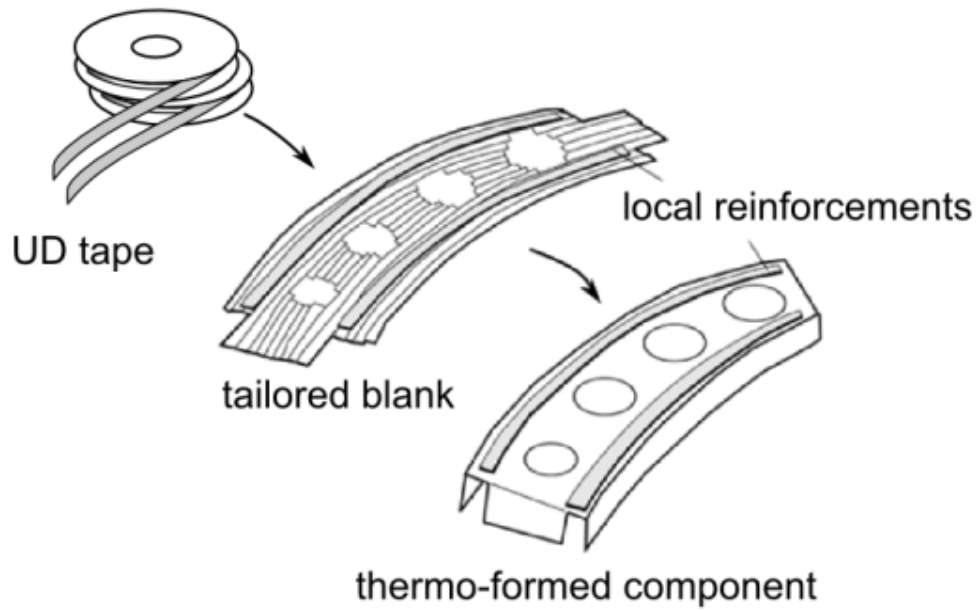
DTC

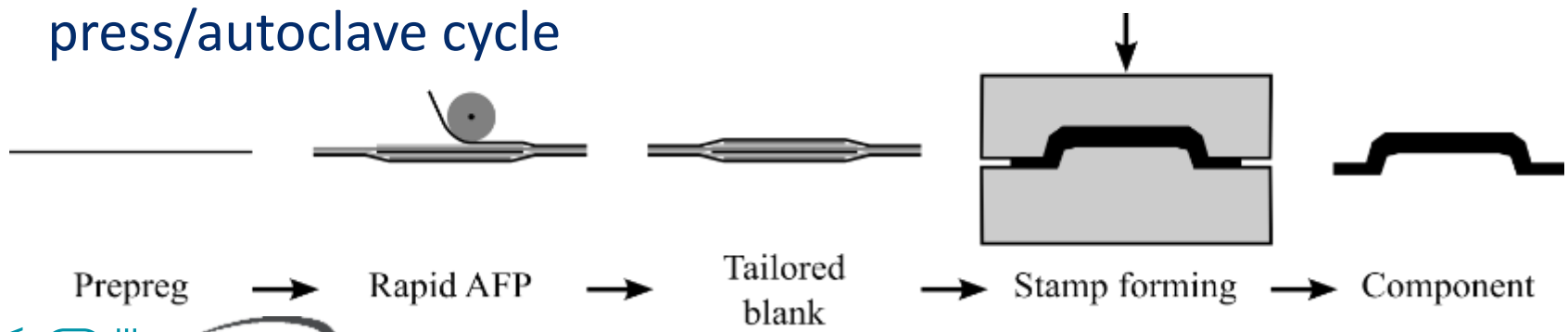


DTC

Rapid AFP + Stamp Forming

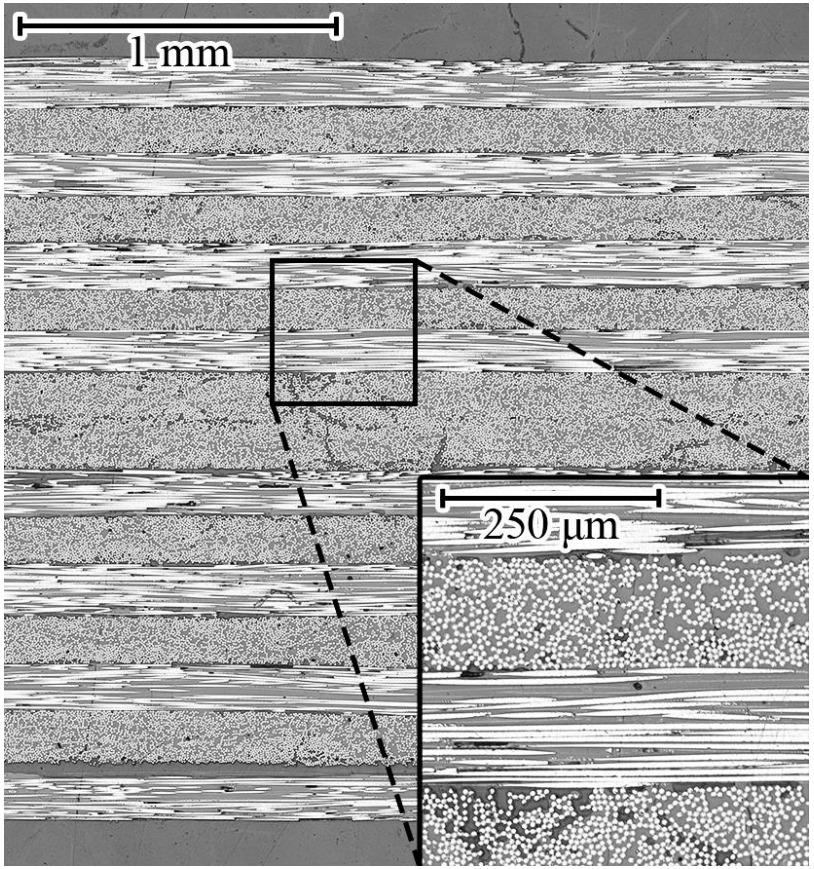
- **Tailored lay-up:** Improved performance/weight
- **(Near) net-shape lay-up:** Reduced production scrap
- **Shaping by stamping:** Simple lay-up, complex forming
- **Consolidation by stamping:** High rate lay-up, no additional press/autoclave cycle





Challenge

- Blanks are not fully consolidated
  - High lay-up rate →
    - Intralaminar voids
    - Poor interlaminar bonding
- Consolidation by stamp forming
  - Void elimination + interlaminar bonding
  - High cooling rates → 1-10 s for consolidation



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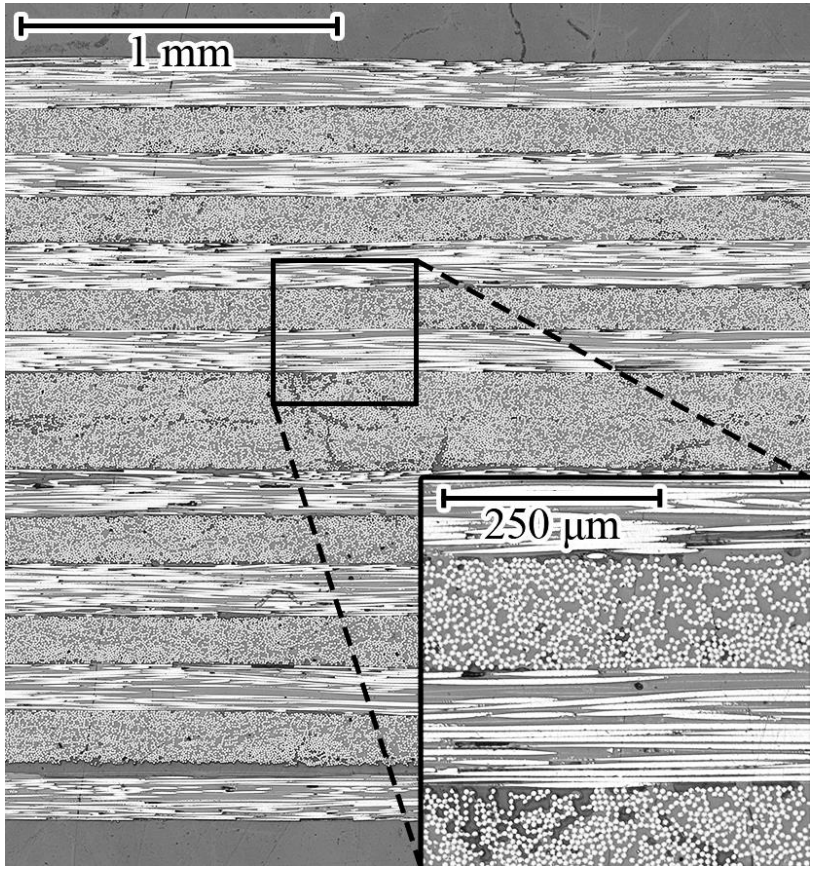

Objective:

1. Develop guidelines and tools for design and processing
2. **Demonstrate industrial application**

Demonstrator Design and Manufacturing

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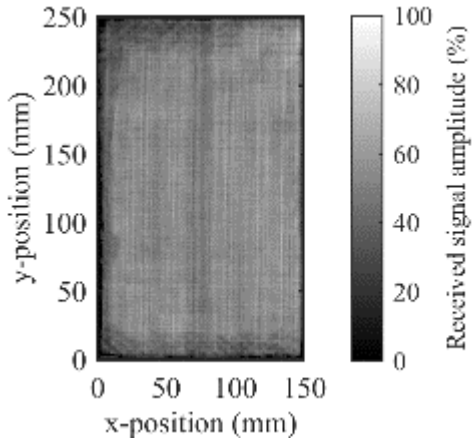
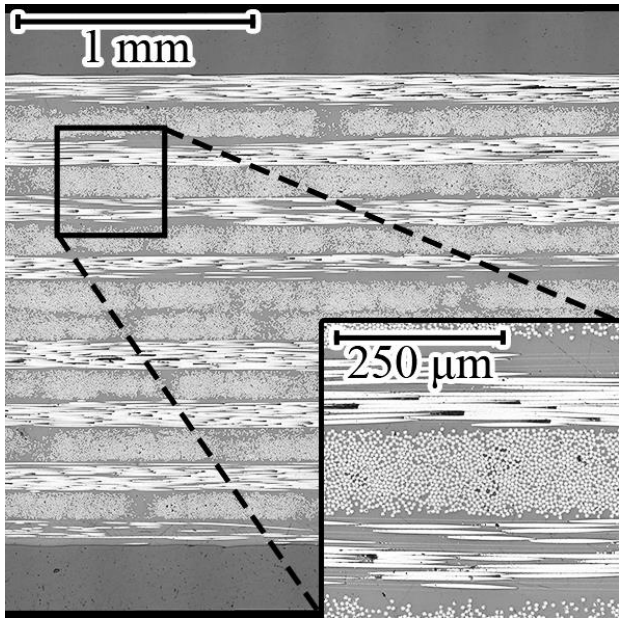
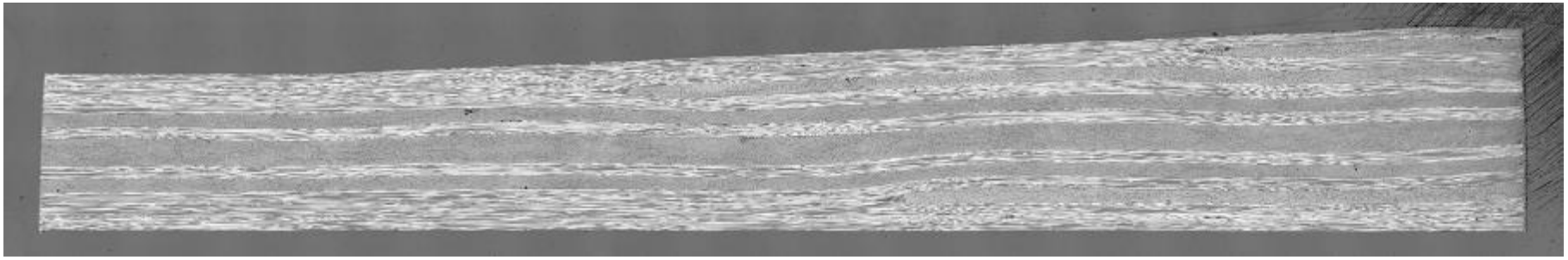
Previous work

- Developed design & processing guidelines
- High consolidation quality obtained
- Material and lay-up process are key

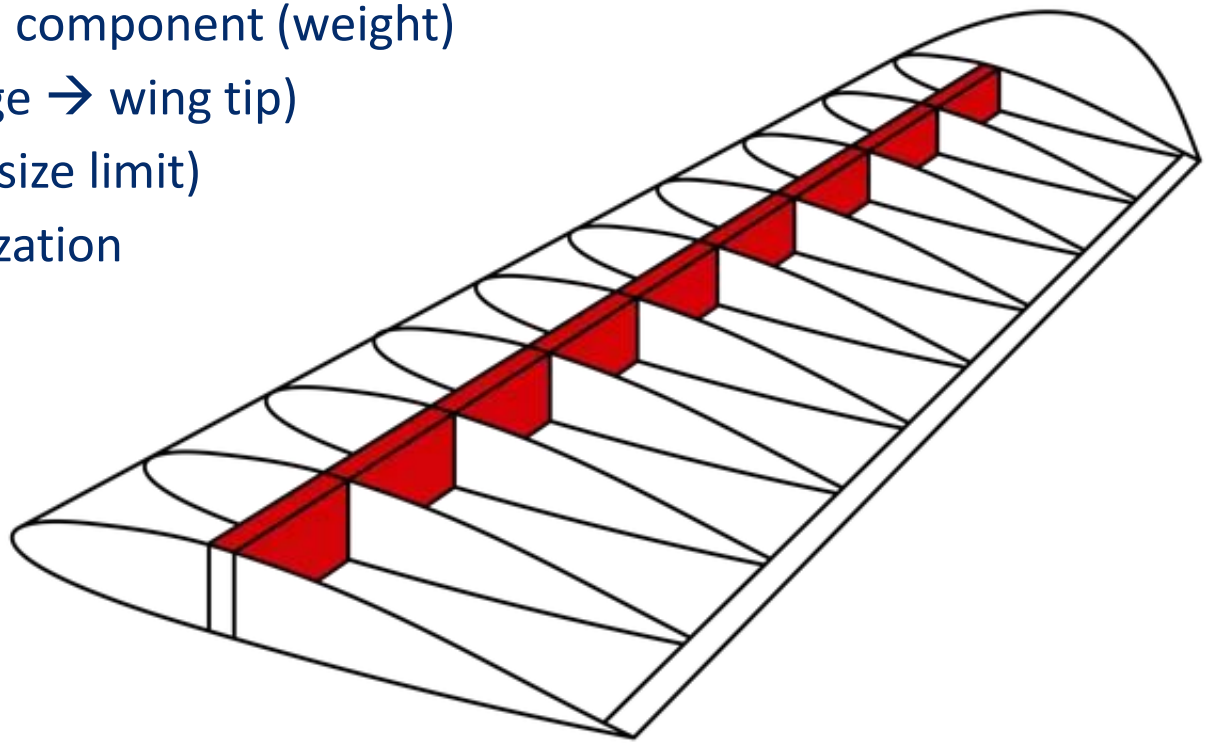




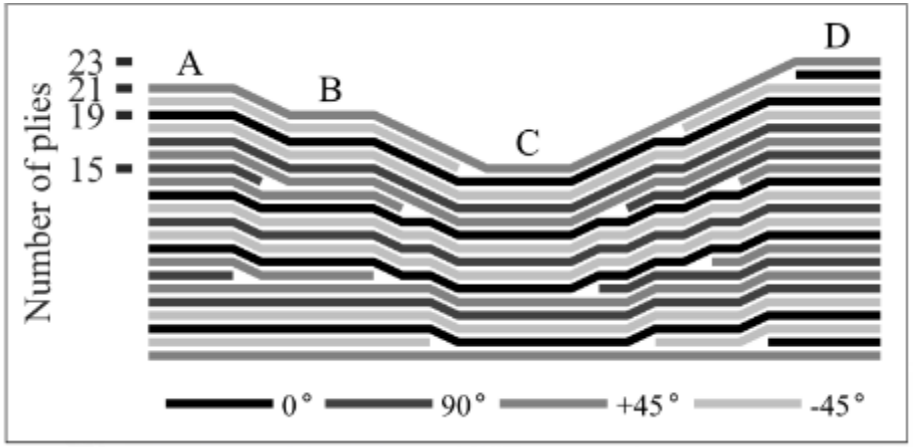


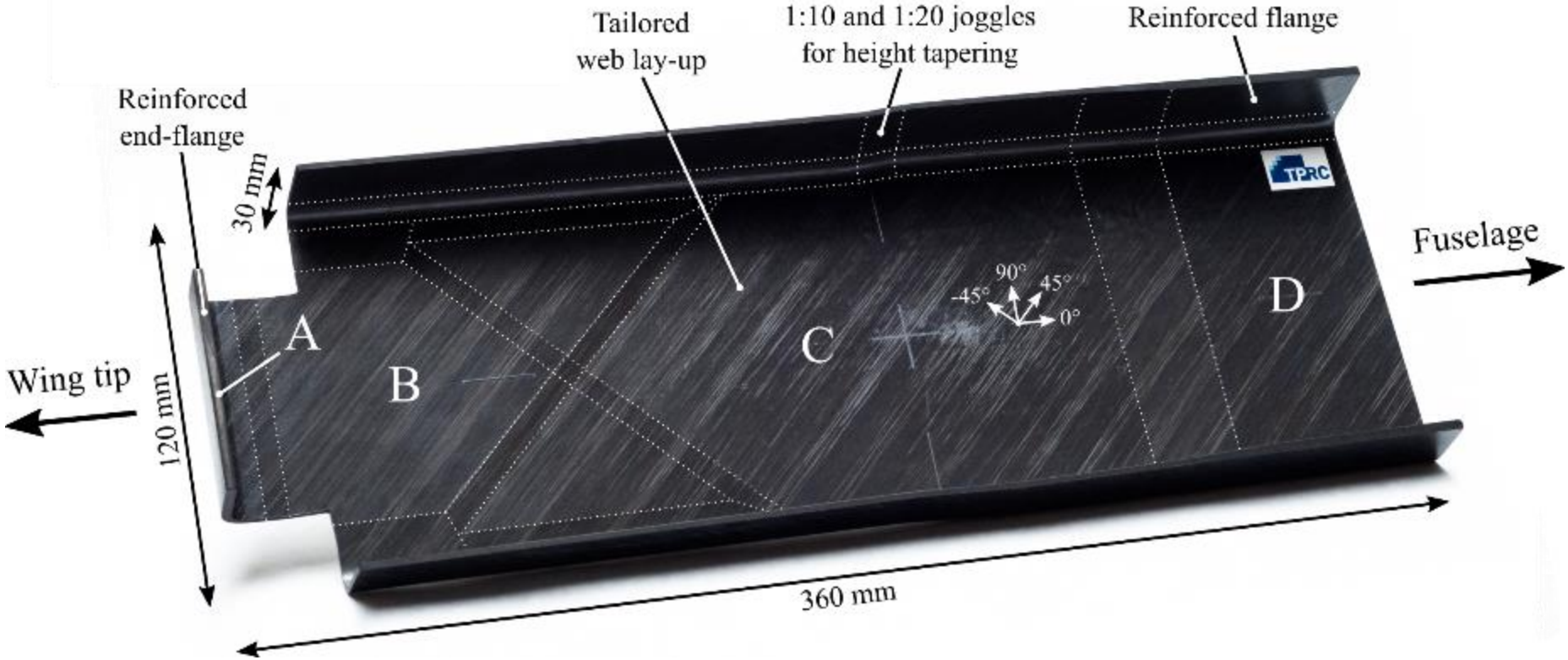
Application demonstrator

- Realistic component: spar of a (small) wingbox
  - Design in cooperation with Fokker Technologies
  - Structural aerospace component (weight)
  - Varying load (fuselage → wing tip)
  - Small section (press size limit)
  - No structural optimization



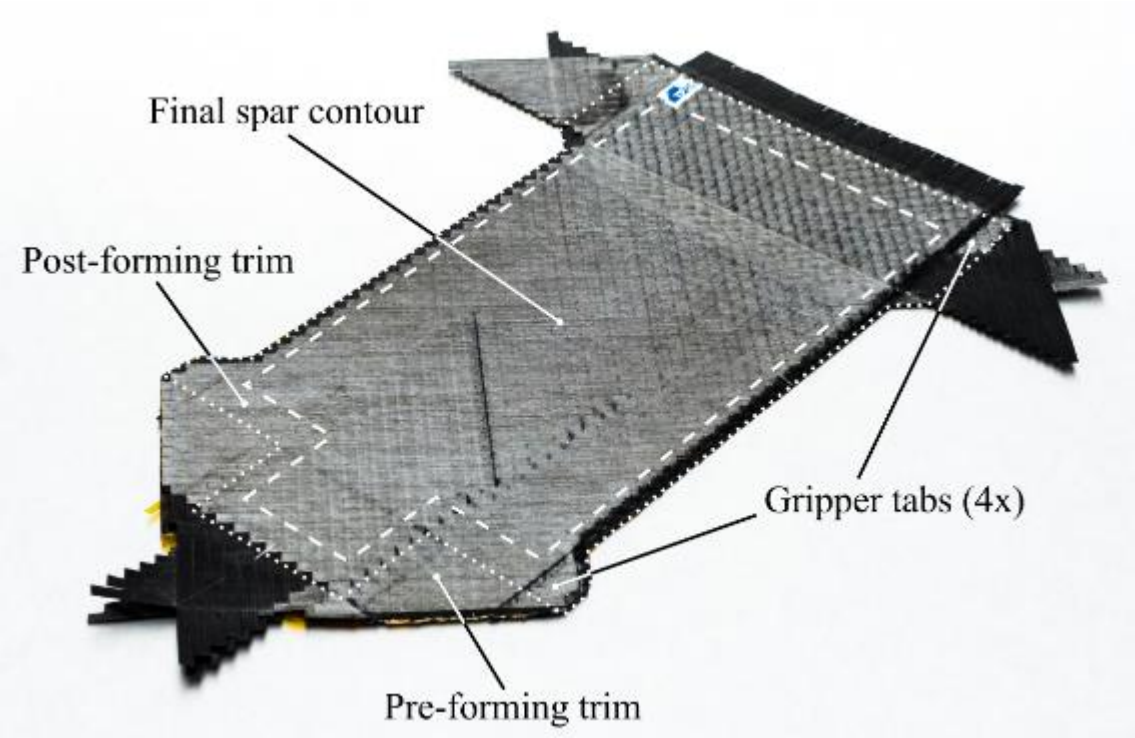
Spar design


Number of plies
23
21
19
15
A
B
C
D
0°
90°
+45°
-45°


Tailored web lay-up
1:10 and 1:20 joggles for height tapering
Reinforced flange
Reinforced end-flange
30 mm
Fuselage
Wing tip
120 mm
360 mm
A
B
C
D
90°
45°
-45°
0°
TPRC

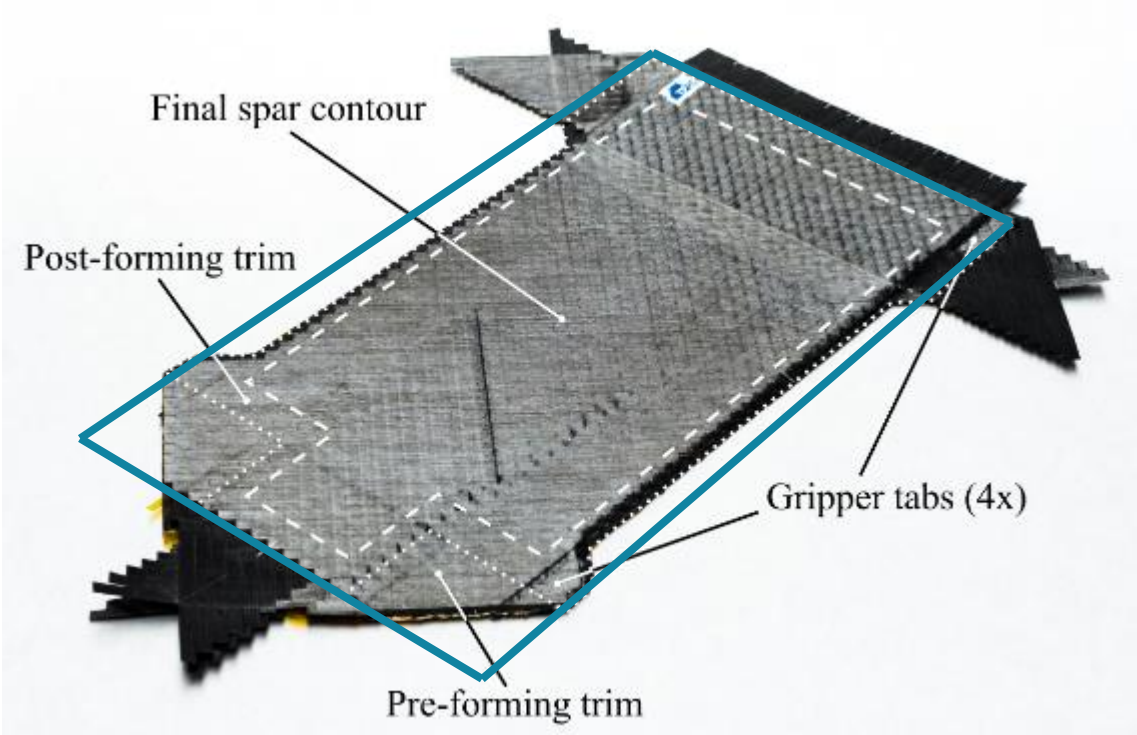
Blank design – contour

- Near net-shape lay-up
  - AFP minimum fiber length: ~100mm (pre-forming trim required)
  - 10 mm post-forming trimming edge (could be reduced to 3-5 mm)



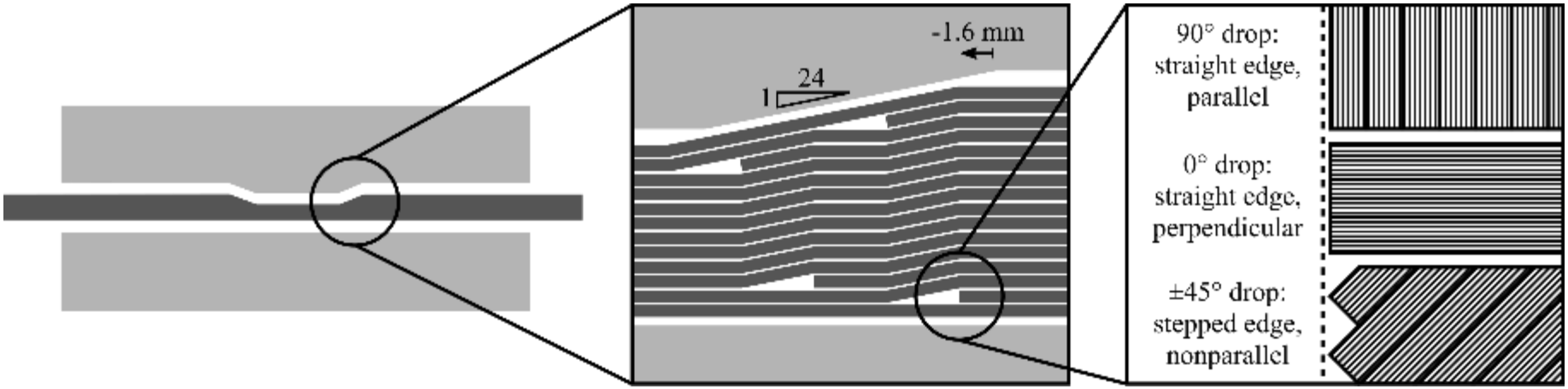
Blank design – contour

- Near net-shape lay-up
  - AFP minimum fiber length: ~100mm (pre-forming trim required)
  - 10 mm post-forming trimming edge (could be reduced to 3-5 mm)
  - 33% less trimming scrap (compared to 23-ply, lay-up D, 400x230 mm^2)



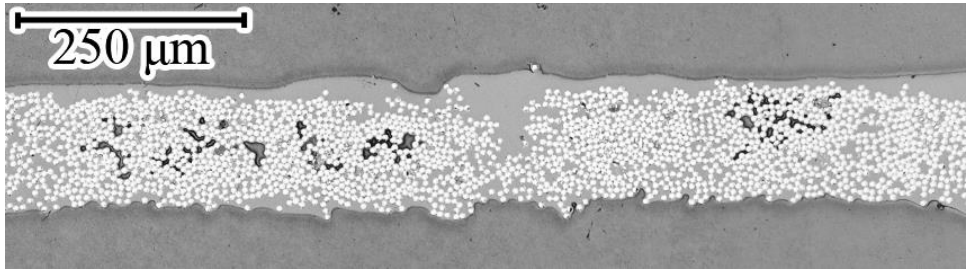
Blank design – ply-drops

- 1:24 tapering, interleaving
- Extend plies 1.6 mm into tapering region
- Transverse flow is key



Material & Lay-up

- Material: ¼” Cytec APC-2 C/PEEK
  - Matrix-rich surface
  - Intralaminar voids



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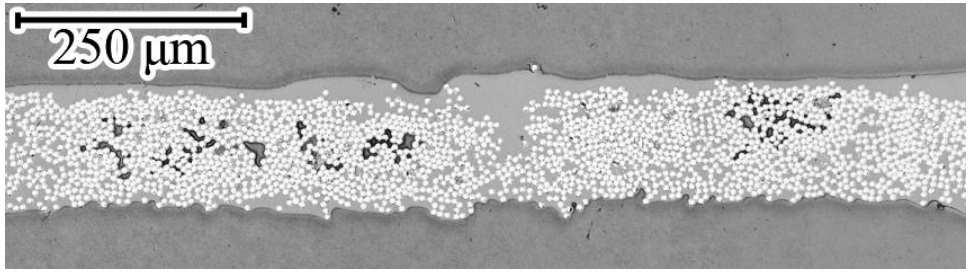
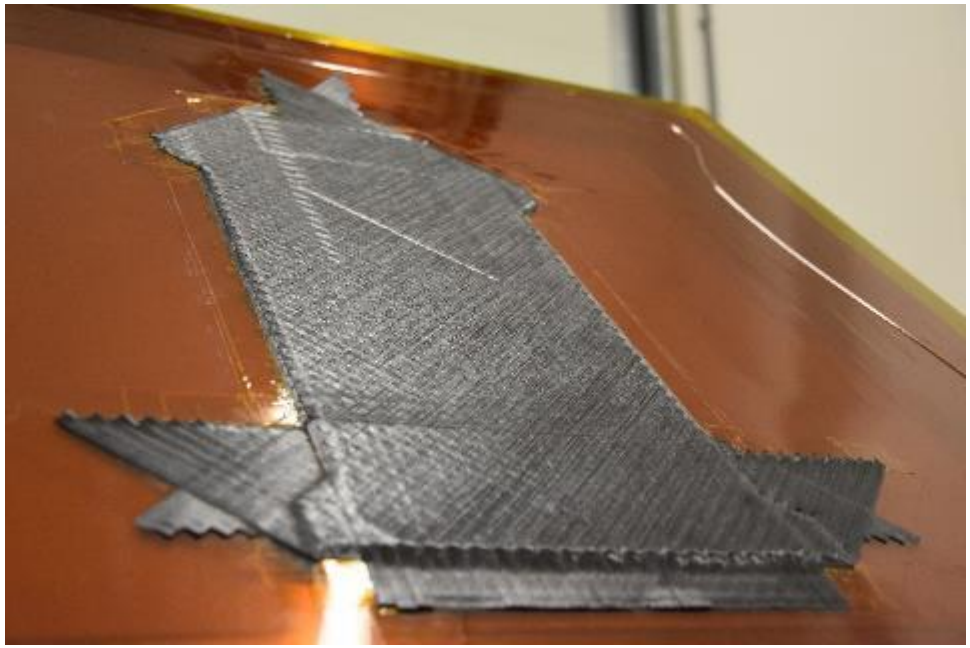
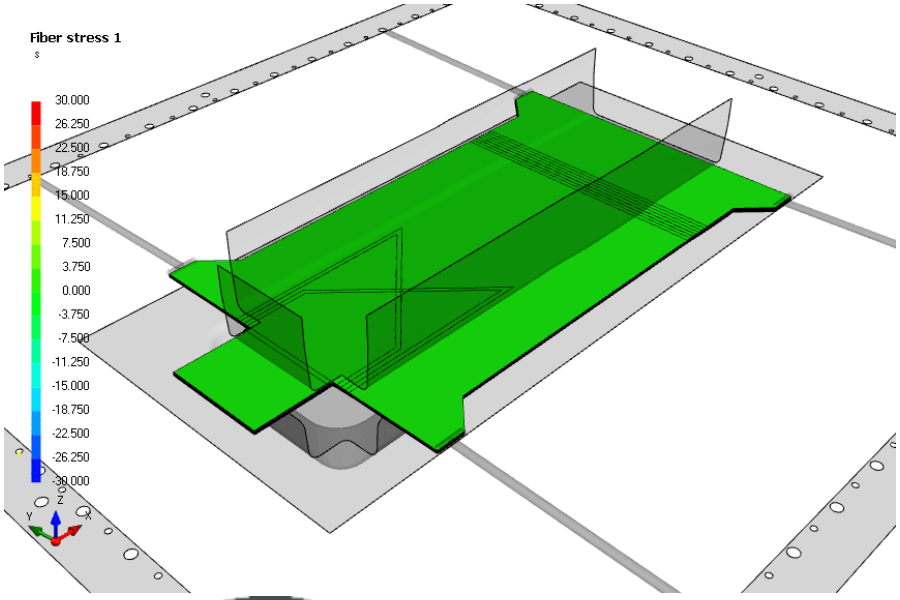


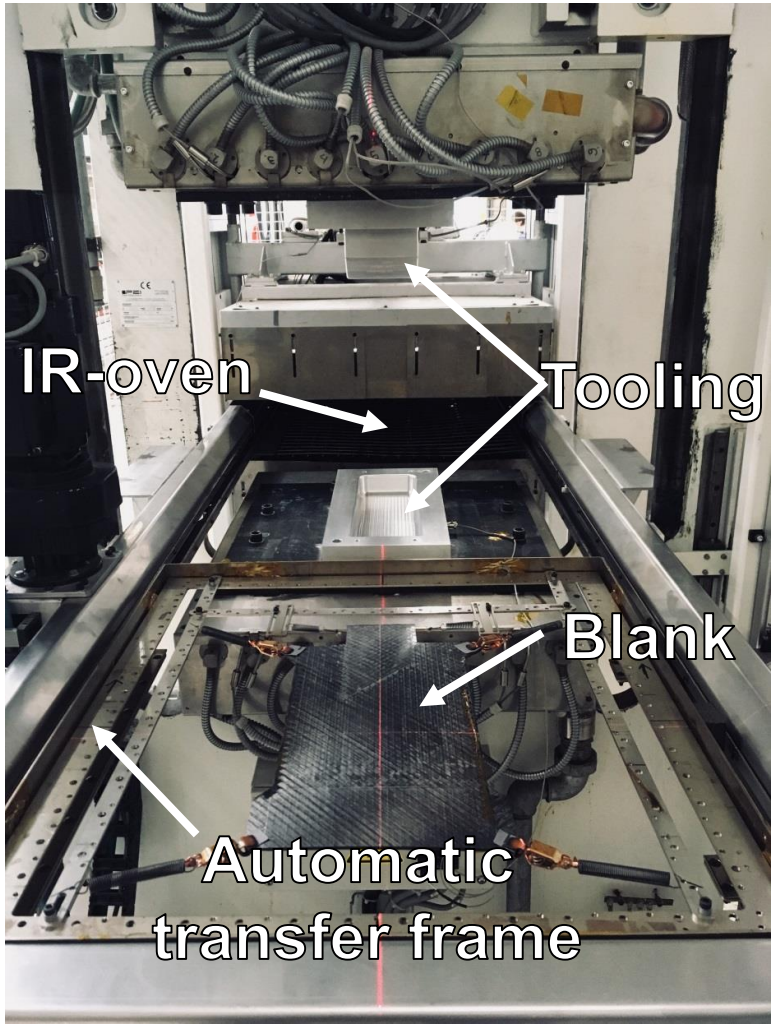
- Lay-up
  - Coriolis Composites AFP machine @ TPRC
  - Single tow @ 200 mm/s: 68 min
  - 8-tow @ 500 mm/s: <10 min (Coriolis CADFiber simulation)



Stamp forming

- AniForm forming simulations
- Heat blank in IR-oven (420°C): 180 s
- Form + consolidate (100 bar, 250°C): 60 s





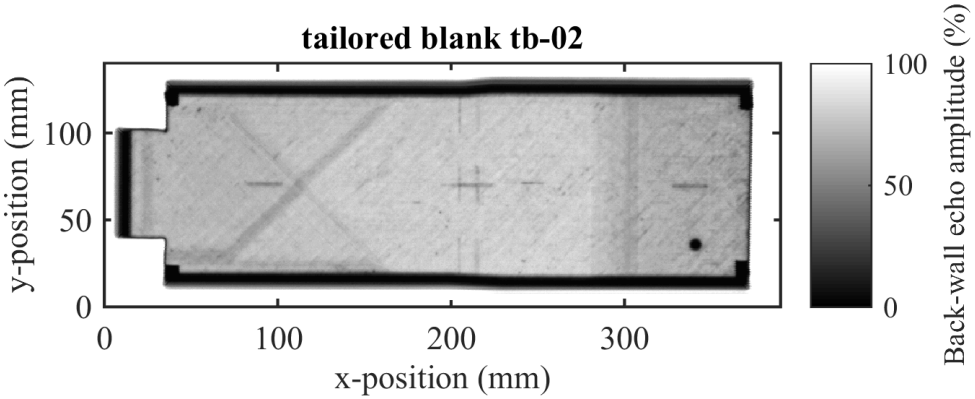
Results

Results – Consolidation quality

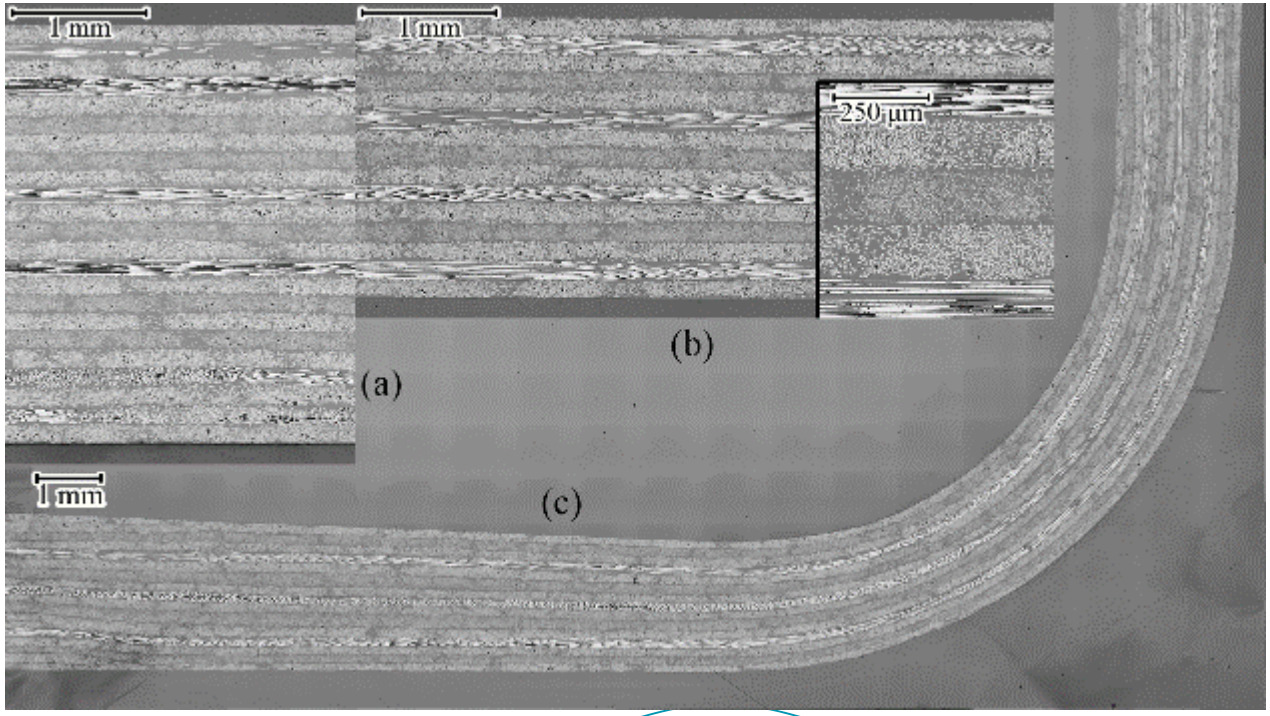
- Visual inspection of surface quality: OK

Results – Consolidation quality

- C-scan (web): No defects
- A-scan (flanges): No defects
- Microscopy: << 1 % voids

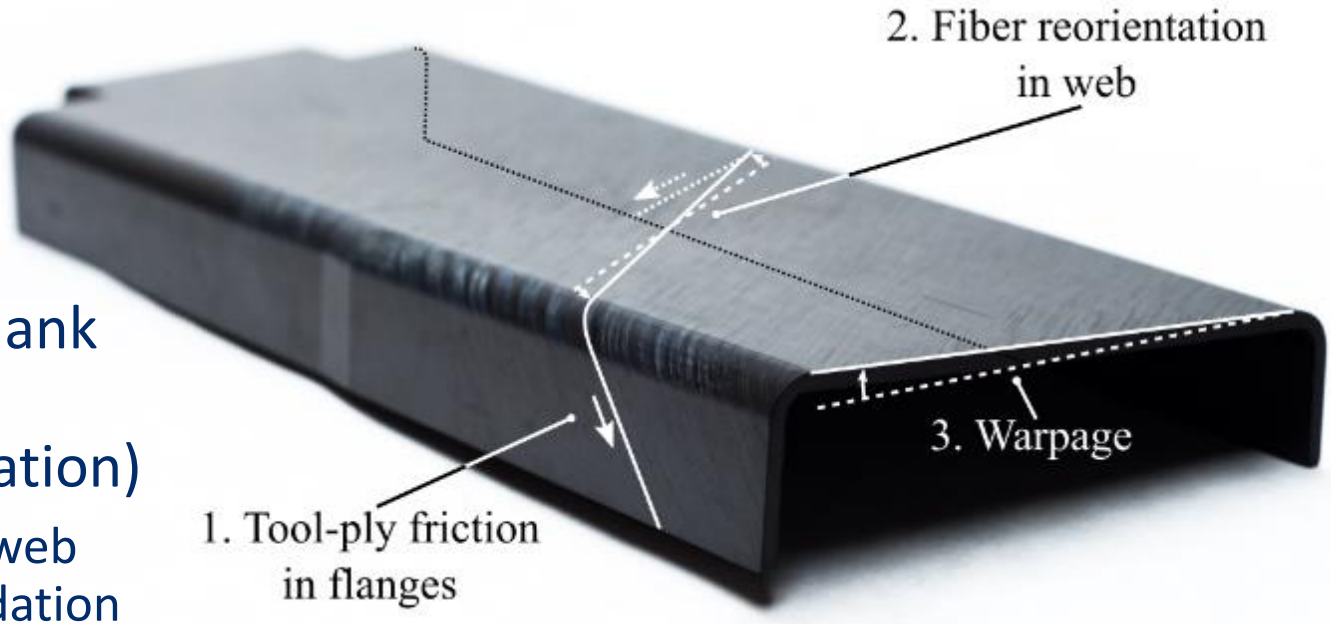


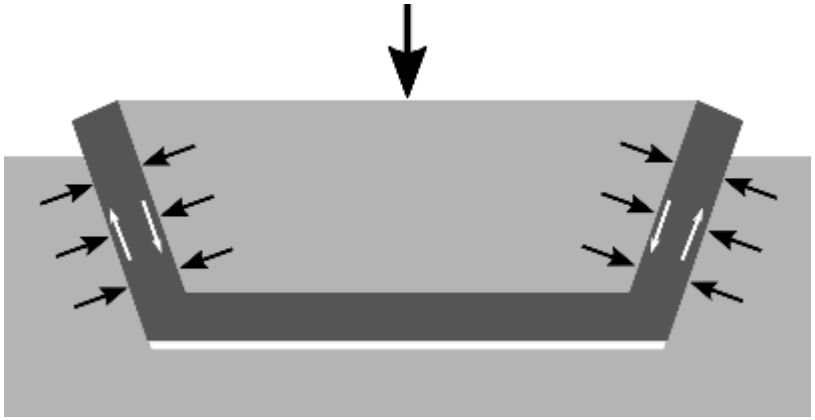
- (a): Zone D
- (b): Zone C
- (c): Transition B>C



Results - Defects

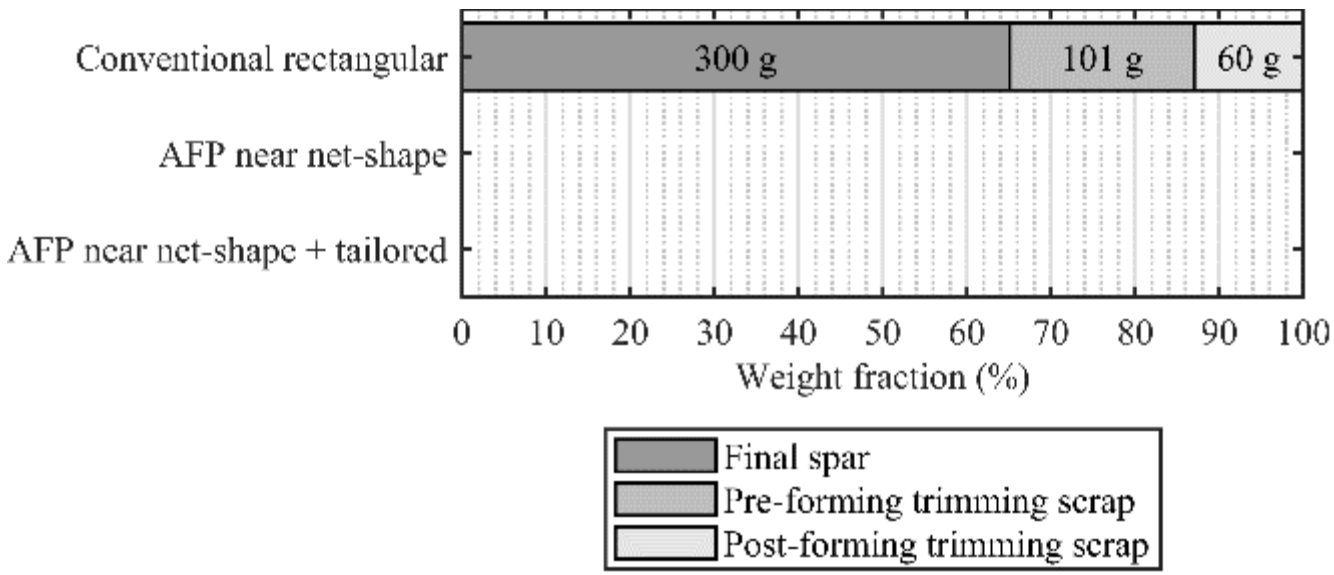
- Warpage
- Sensitive to blank thickness (+ deconsolidation)
  - Rough area in web + poor consolidation
  - Ply splits





Results – Material savings

- Reduced scrap & weight
  - Press-consolidated reference: 461 g (100%) (23-ply (D), 400x230 mm²)



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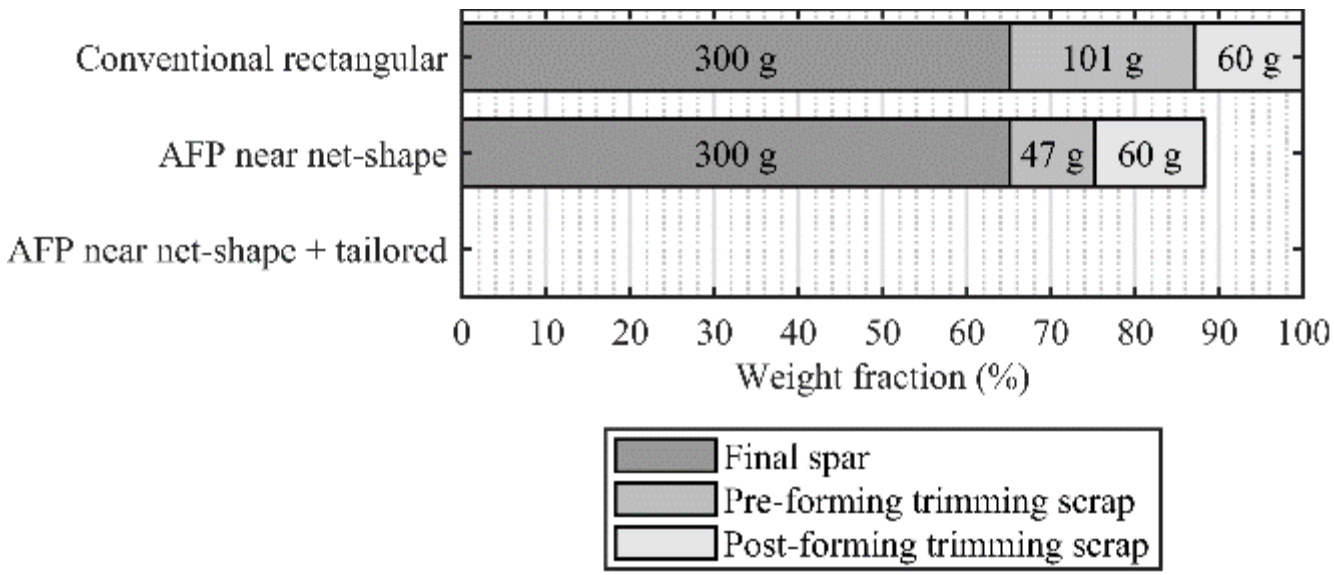
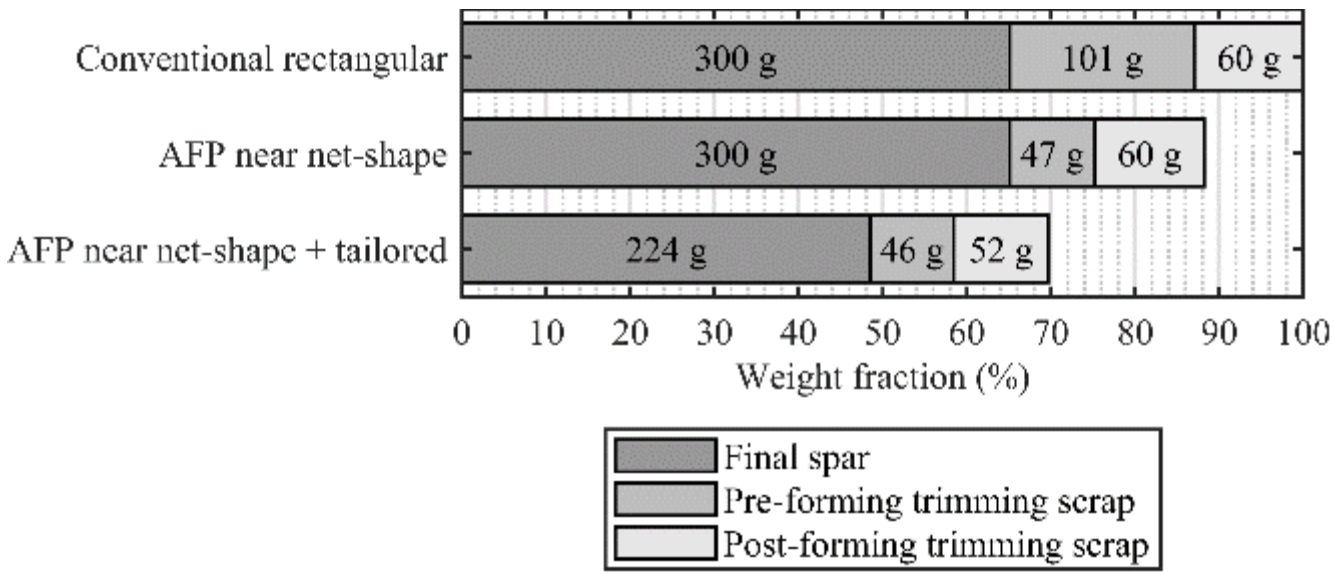
  - Press-consolidated reference: 461 g (100%) (23-ply (D), 400x230 mm²)
  - Near net-shape lay-up: -12% (-33% scrap)



Results – Material savings

- Reduced scrap & weight
  - Press-consolidated reference: 461 g (100%) (23-ply (D), 400x230 mm²)
  - Near net-shape lay-up: -12% (-33% scrap)
  - Tailoring: -25% part weight (Note: no structural optimization)
  - Total material savings: 30%



Conclusion

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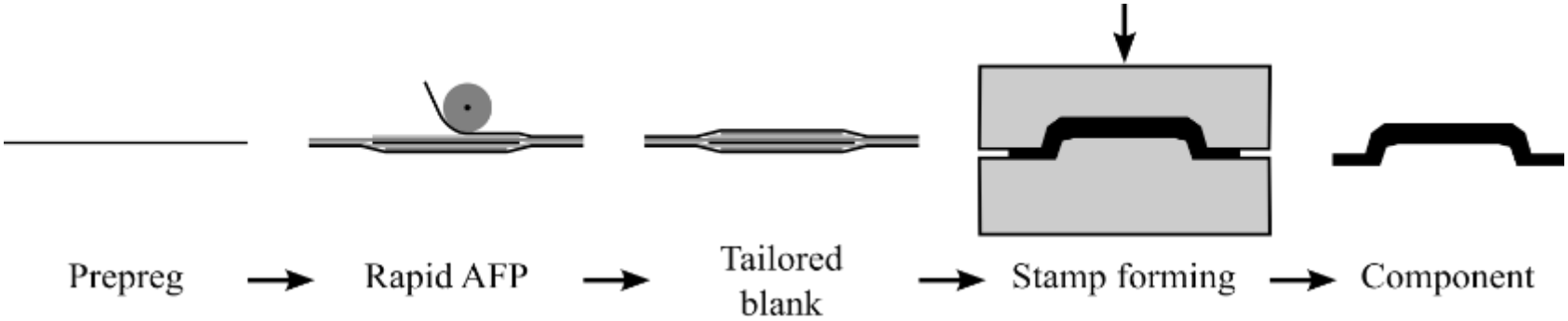
- New process route for manufacturing of tailored components
  - Rapid flat lay-up, complex forming + consolidation
  - Material savings by near net-shape lay-up
  - Weight savings by tailoring
  - No additional preconsolidation

- Demonstrated on component
  - Good consolidation
  - Sensitive to thickness



Thank you

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