NATIONAL COMPOSITES CENTRE

Bristol Composites Institute

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New sustainable materials and manufacturing processes reduce steering defects during automated layup

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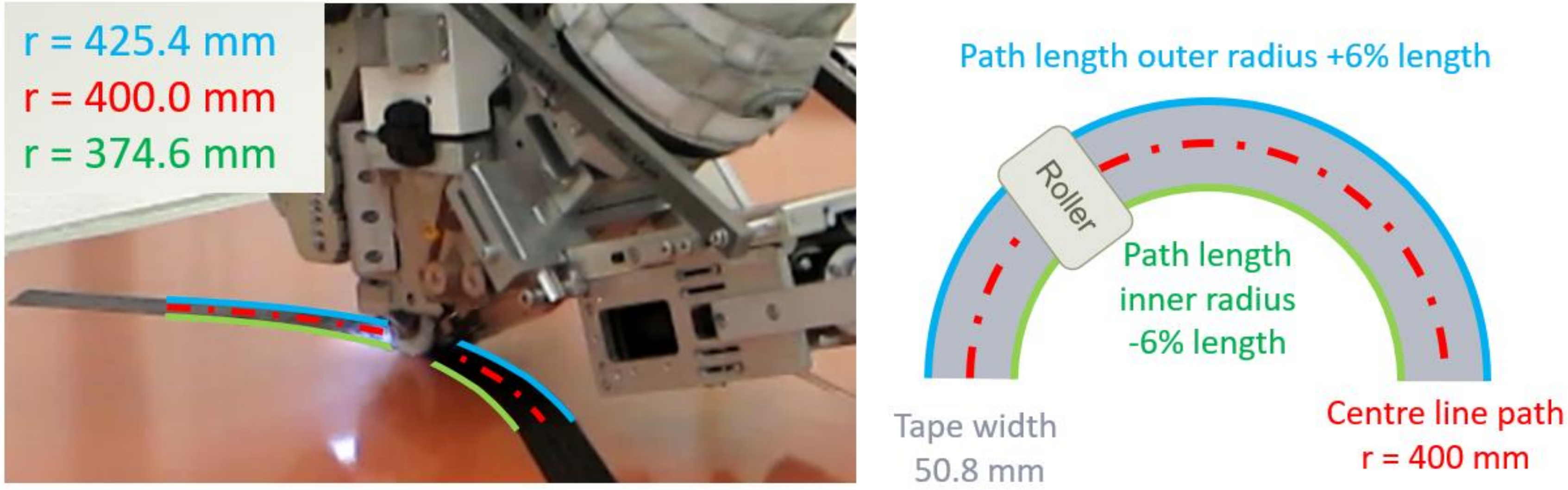
Automated Deposition of REcycled Prepreg tapes

- Next-generation aircraft will require more efficient, lighter components, combined with a transition to Net Zero
- This will require intricate tow steering to carry complex load paths, while maintaining quality and rate
- Critical Steering Radius (CSR) is a key manufacturability parameter for layup program definition
- ATL, although high rate, has a significantly reduced steering capability in comparison with AFP
  - ➢ **RTS has shown the capability to significantly improve CSR for wide tapes**
  - ➢ **Reclaimed short fibre tapes may also improve CSR, with added sustainability benefit**



Example of tape path length discrepancy [1]

Automated Deposition of REcycled Prepreg tapes

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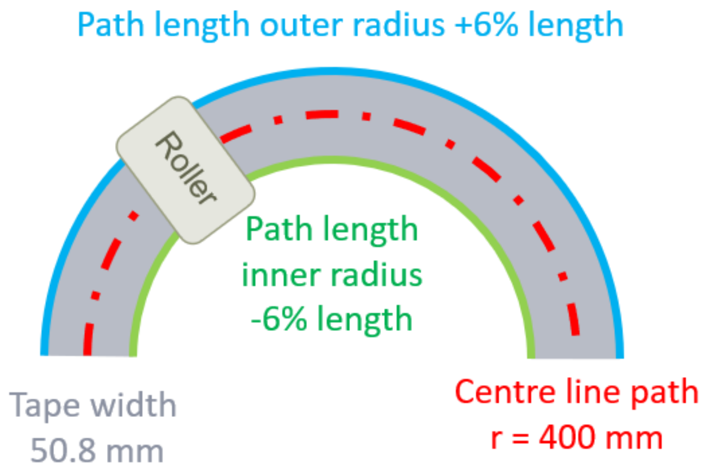
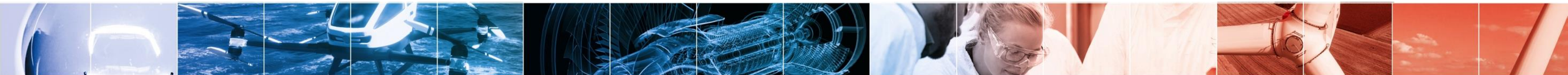
- ATL, although high rate, has a significantly reduced steering capability in comparison with AFP
  - ➢ **iCOMAT's Rapid Tow Shearing (RTS) process has shown the capability to improve CSR for wide tapes**
  - ➢ **Reclaimed short fibre tapes may also improve CSR, with added sustainability benefit**

Project Objectives:

- Demonstrate that aligned short fibre materials can be deposited using automated layup techniques
- Assess the CSR and material quality against a baseline, using two automated layup processes:
  - ➢ ATL
  - ➢ RTS





Recycled prepreg material production (AFFT)

- End-of-life reclaimed fibres used
  - ➢ Reclaimed from post-industrial bobbins
- Semi-preg material: resin applied on one side of fibres
  - ➢ Fibre AW: 49.67 ±1.3gsm
- Manufacturing challenge: ATL lays dry side down, limiting tack
  - ➢ Mitigation: use continuous prepreg as a tacky substrate

LINEAT Capability
Engineering team automating and upscaling fibre alignment technology, AFFT1 pilot line in NCC Filton for 100mm wide pre-preg tape production

	Lineat AFFT (short fibre)	Baseline Continuous (UD)
Tape width	75mm	75mm
Fibre length	4mm	up to 50,000mm
Resin	SHD MTC400-1	Hexcel 8552
Tape density estimate	100gsm	134gsm
V_f estimate	40%	67%

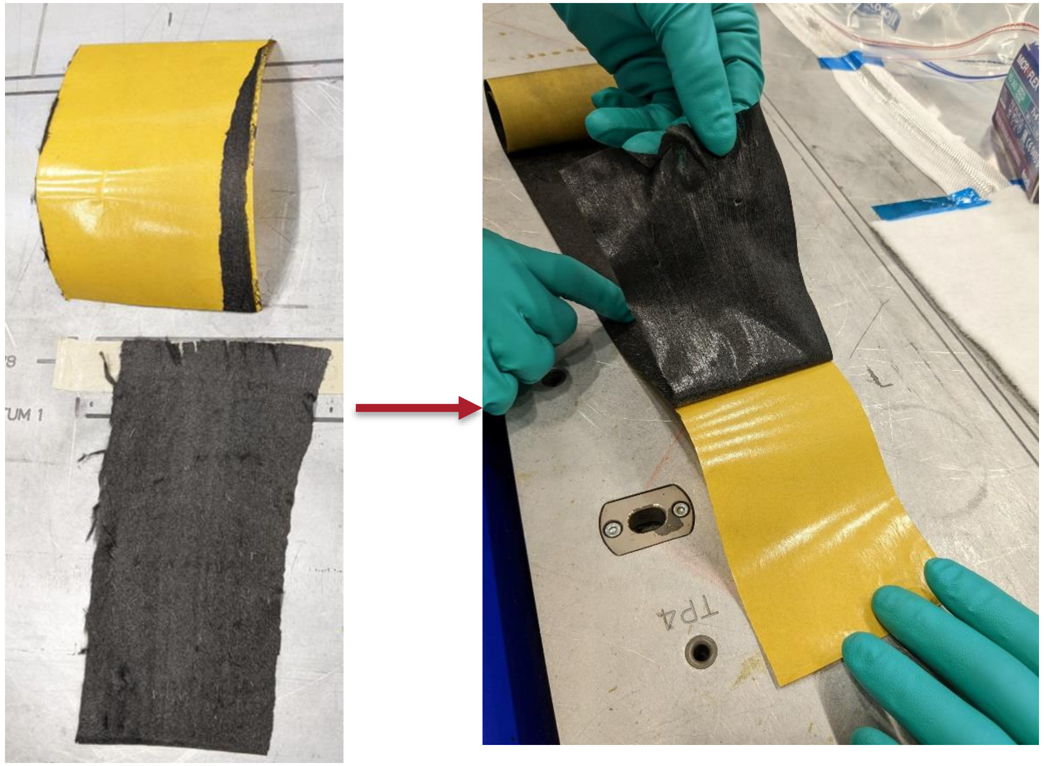
Material parameters

Post industrial recovered rCF

AFFT tape

Recycled prepreg material development

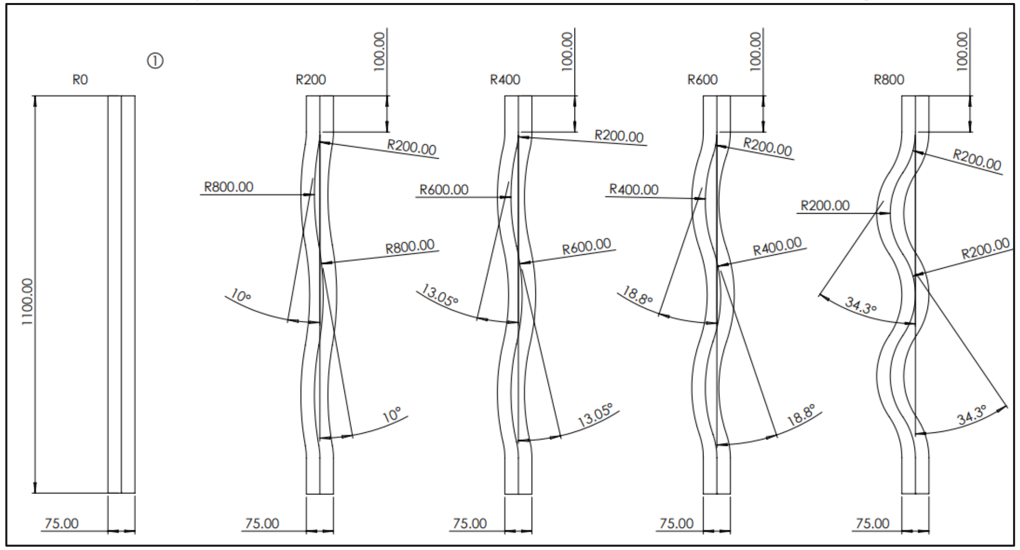
- Initial tape samples displayed significant tearing and poor-quality edges
- Possible cause: resin film narrower than dry tape
  - ➢ This may cause fibres to stray beyond film edge
- Mitigations:
  - ➢ Edge cleaning was implemented on AFFT1 machine to smooth edge
  - ➢ Tape was slit from the centre (100mm to 75mm) to produce a sharp edge on each side
- Second sample was much higher quality!



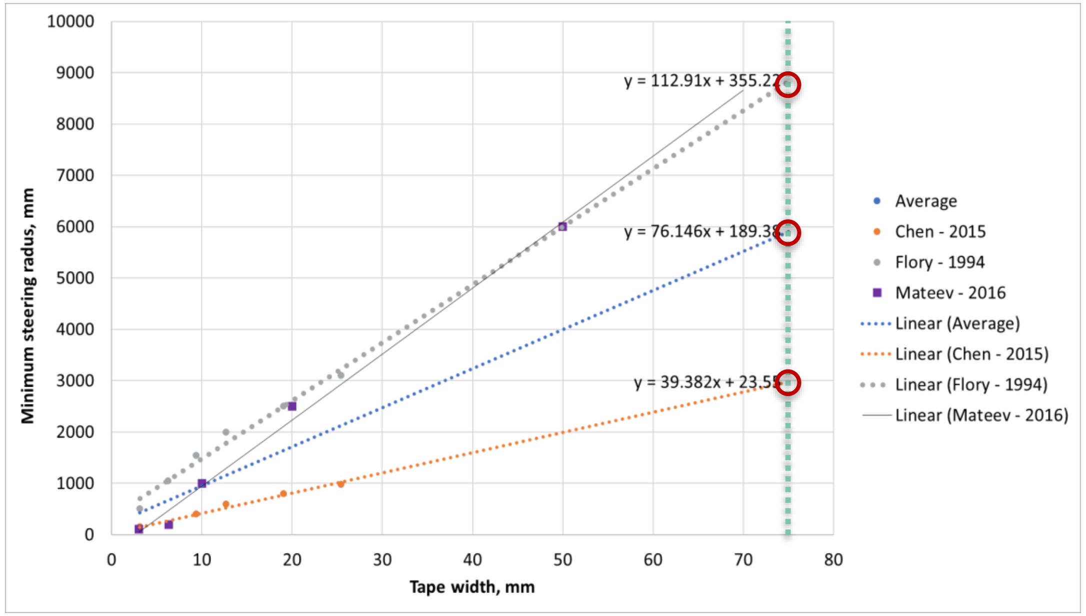
Lineat process improvement: ‘Manual Tape Laying’

Automated lay-up steering radii selection

- Steering radii selected based on literature and past projects for each material type
  - ➢ 75mm ATL steered to 10m previously
  - ➢ AFP values selected from literature
  - ➢ RTS values and dimensions selected to align with AFP and past experience
- Overlap of all 3 materials at 0.8m steering radius



RTS lay-up dimensions (mm)



Minimum steering radii extrapolated from literature (ADFP)

Matveev et al. (2016). Understanding the buckling behaviour of steered tows in Automated Dry Fibre Placement (ADFP). Composites Part A: Applied Science and Manufacturing, 90, 451–456.

Steering radius (m)	8.00	6.00	4.00	2.00	1.50	1.25	1.00	0.80	0.60	0.50	0.40	0.20
ATL												
AFP												
RTS												

Deposited steering radii reference chart

RTS results, baseline

- Quality was good for both materials for **all** radii laid (down to 200mm)
  - ➢ Defects are minor when they occur
- Material was shiny and difficult to scan or see in pictures
- **Critical steering radius: <200mm**

Continuous material with RTS process (200mm)

Minimal noted defects

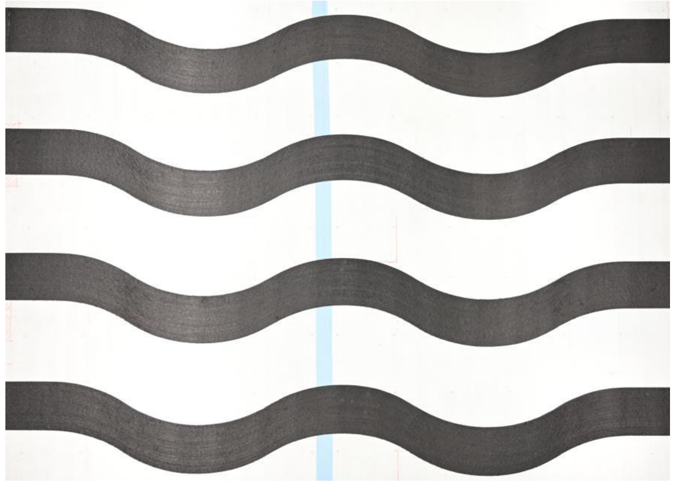
RTS results, AFFT

- Quality was very good for both materials for **all** radii laid (down to 200mm)
- Loose fibres (poor alignment) observed on recycled material top (dry) surface
  - ➢ **ATL lays dry side down, RTS lays dry side up**
- Small sheering wrinkles also observed In tight radii
- **Low tensions required for processing**

Observations:

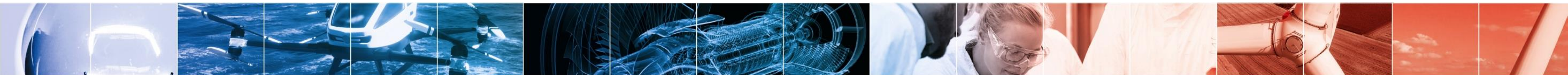
- Extra PPE required due to airborne short fibres

Lineat material with RTS process (200mm)



Shearing wrinkles

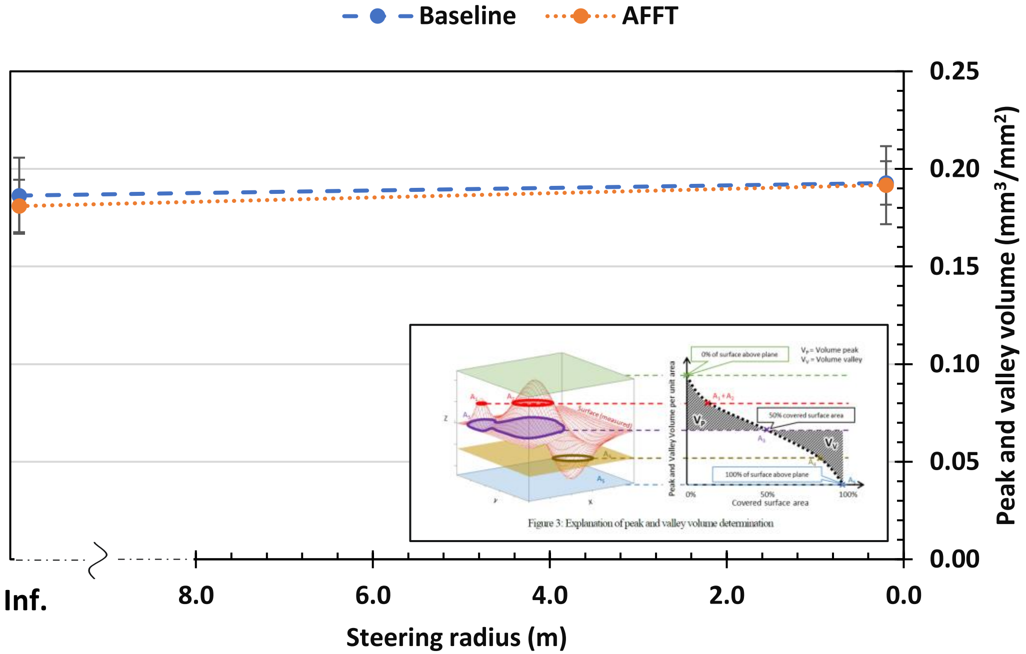
Top surface fuzz



Critical steering radius

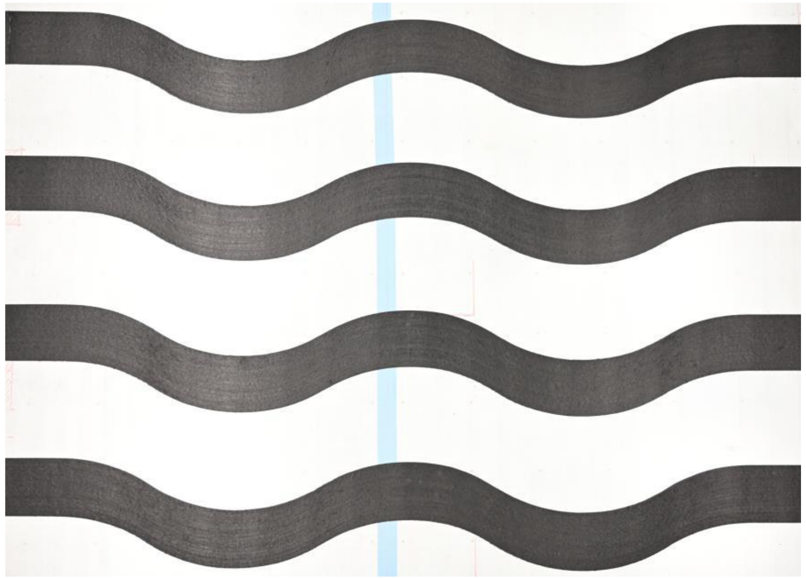
[1] Veldenz, L., Di Francesco, M., Atwood, S., Giddings, P., Kim, B. C., & Potter, K. (2017). Assessment of Steering Capability of Automated Dry Fibre Placement through a Quantitative Methodology. In International Symposium on Automated Composites Manufacturing

- Assessed visually, and quantitatively using peak & valley volume [1]
- No reportable defects, volume not significantly increased from infinite to 0.2m radius
- **Baseline: critical steering radius ≤ 0.2m**
- **AFFT: critical steering radius ≤ 0.2m**

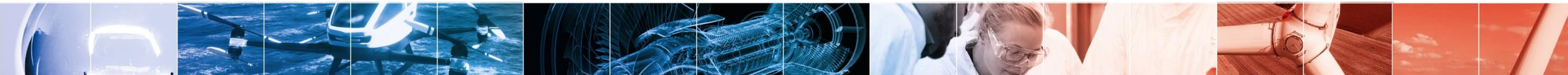


RTS steering results

Lineat material with RTS process (200mm)



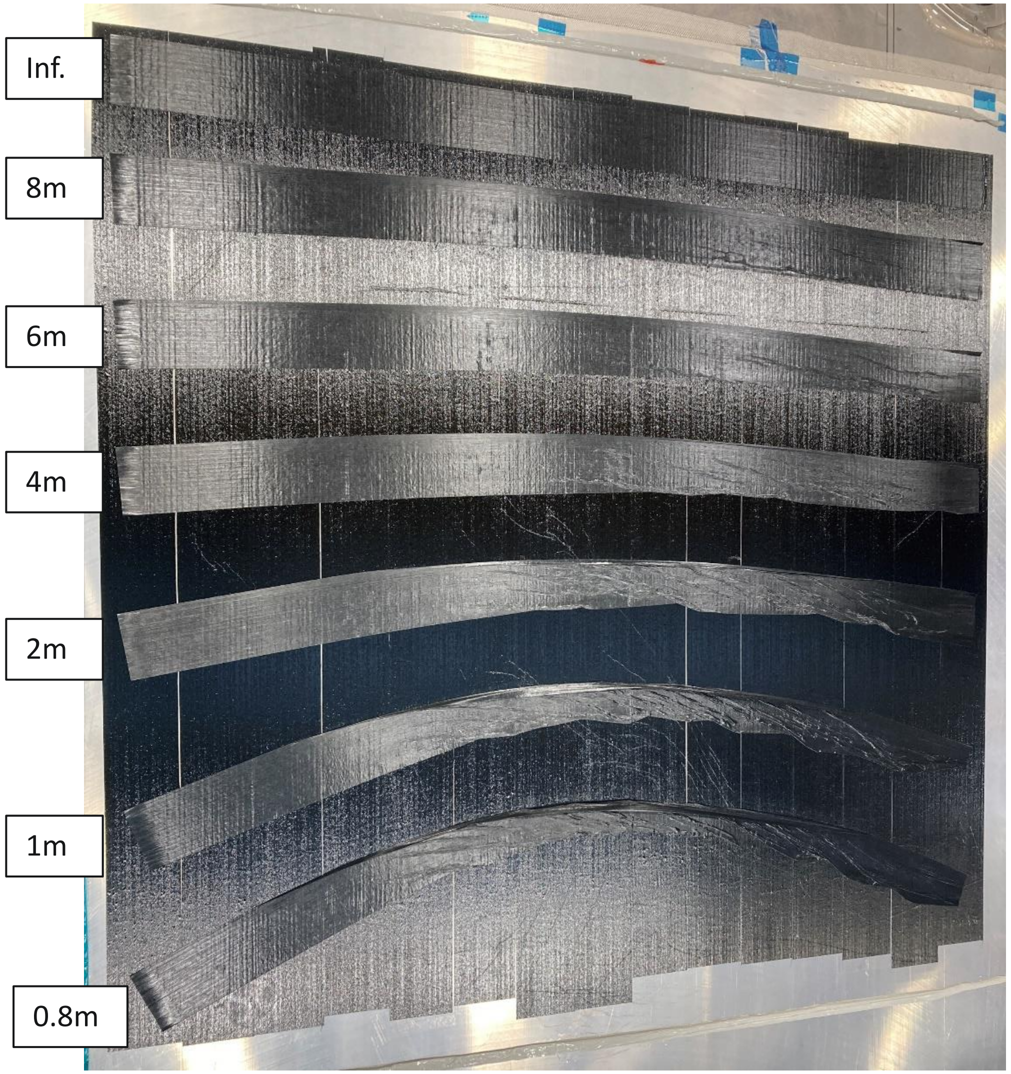
Continuous material with RTS process (200mm)



Baseline steering performance

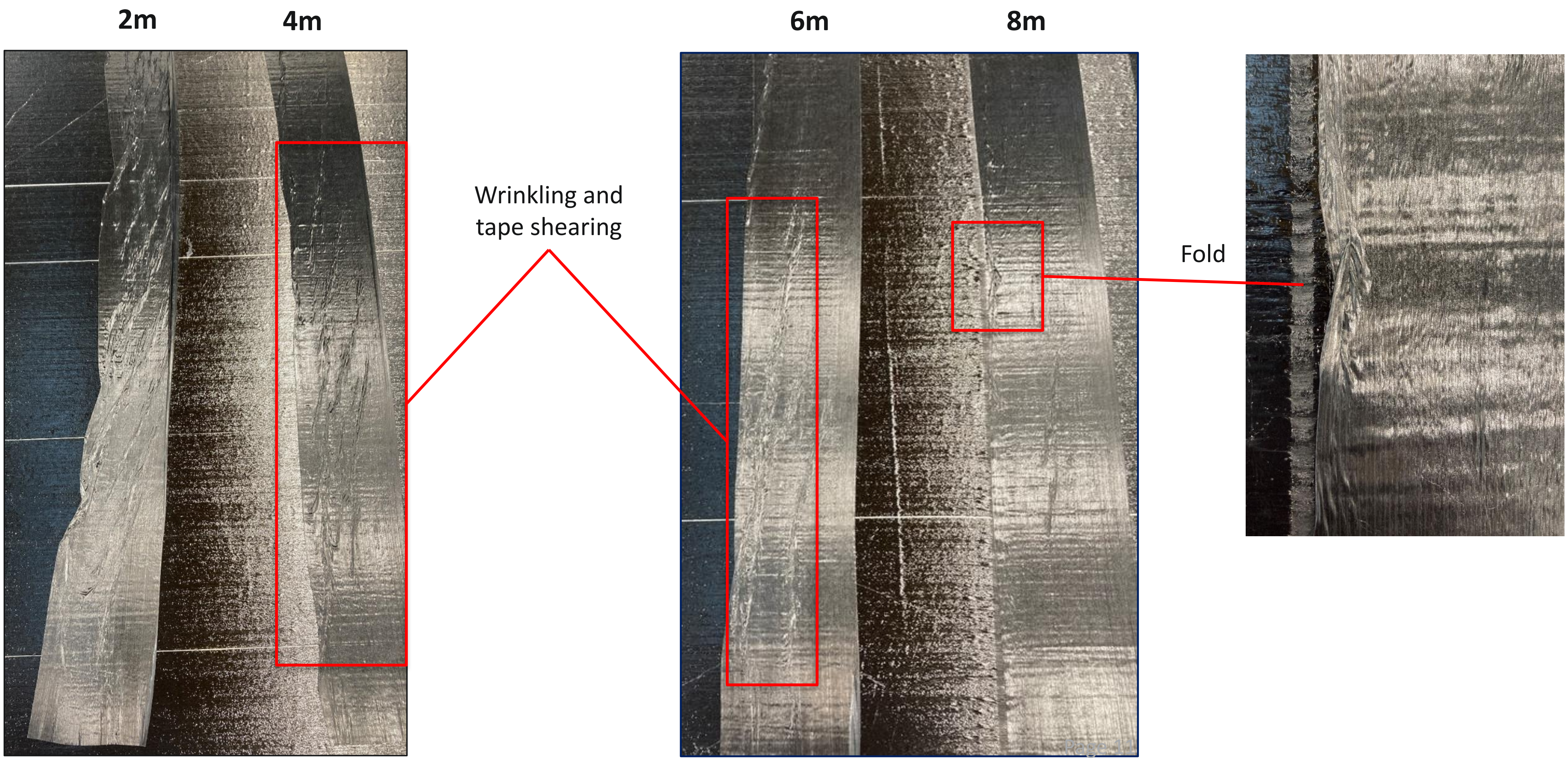
- Steering of ATL tapes is not typically performed
  - ➢ Ability to program steered tapes was not included in CAM package until recently
- Previous trials indicated that steering down to 10m is achievable
- 8m course shows minor defects at tape end
- 6m course shows more significant wrinkling and tape shearing during the last @30% of tape
- 4m tapes and below show significant wrinkling, tape shearing and folding during the last ~50% of tape

Critical steering radius	**7m ±1**



ATL baseline steering map

Baseline steering performance



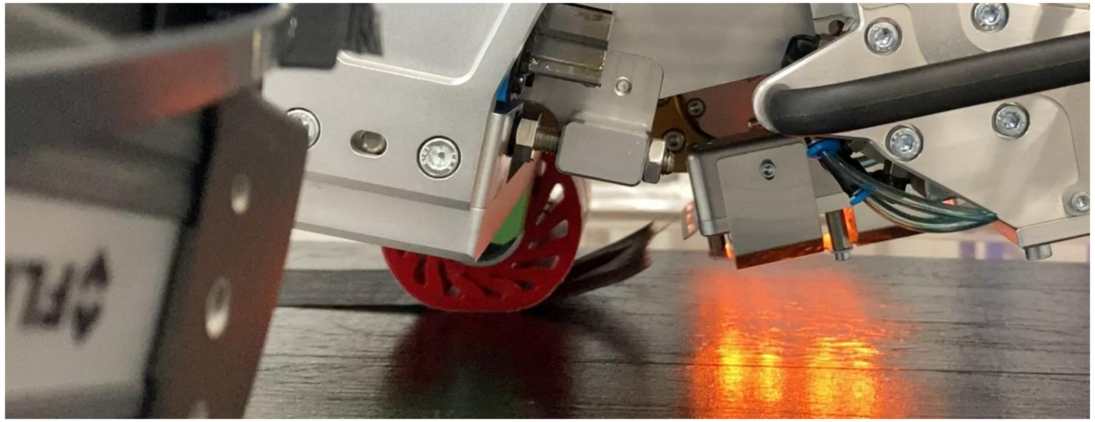
AFFT ATL manufacturing challenges

<u>Roller deposition tape breakage</u>

- Lay-up trials carried out on flat, straight courses, with same baseline material
- Roller tape breakage due to inability to carry applied tension
- Additional lay-up program created to use shoe only
  - ➢ ATL shoe utilises support of backing paper
- Suggested future mitigations:
  - ➢ Increase gsm to improve stiffness
  - ➢ Reduce ATL system tension (not recommended due to additional system dependencies)

ATL roller pre-breakage

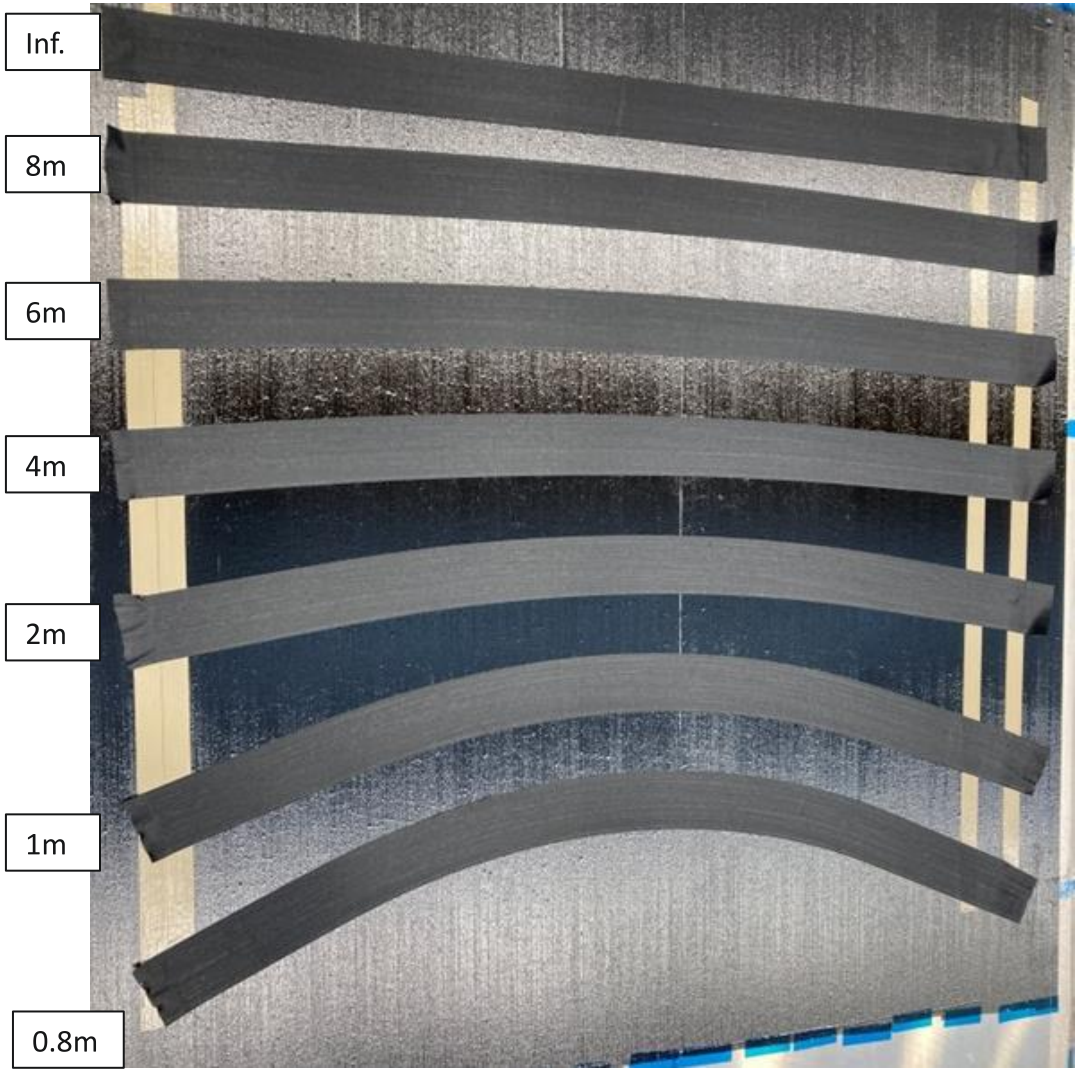
ATL roller post-breakage



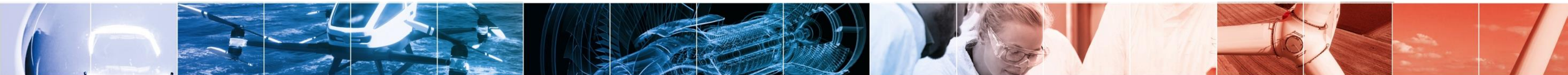
AFFT steering performance

- Final 2 layups performed on a separate day, with second material roll. Possible variation causes:
  - ➢ Material batch variation
  - ➢ Machine / operator variation
  - ➢ Base layer intra-batch variation
- **Steering performance exceeds ATL and is similar to AFP**
  - ➢ Likely due to lower in-plane shear stiffness: fibres can move without deforming
- Suggested fold mitigations: Apply resin to both sides of material (likely requires fibre density increase)

Critical steering radius	0.8m +1.2/-0

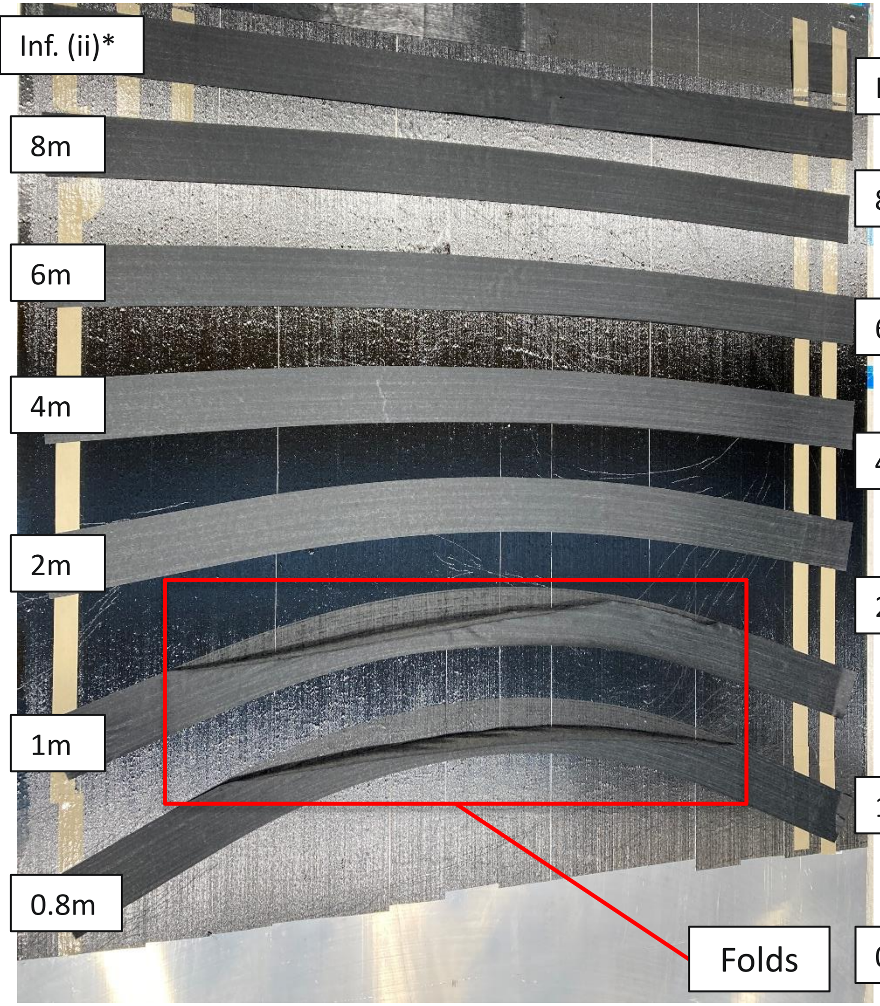


ATL AFFT steering map

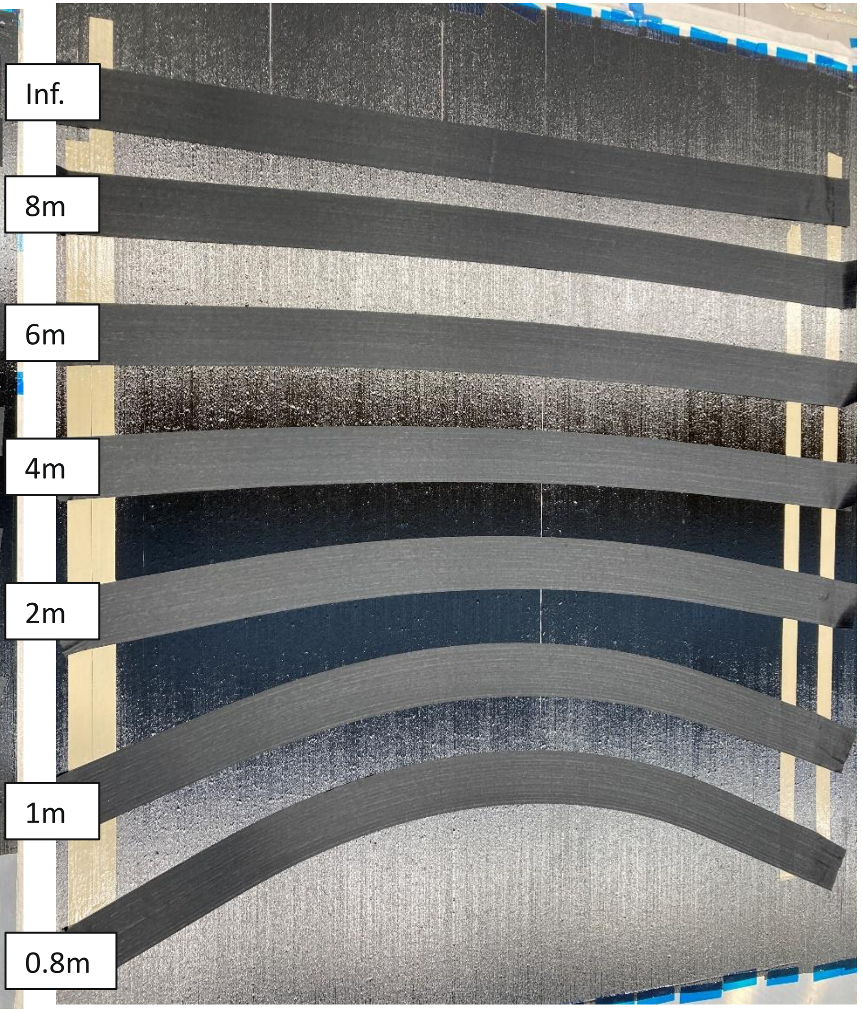


AFFT steering performance

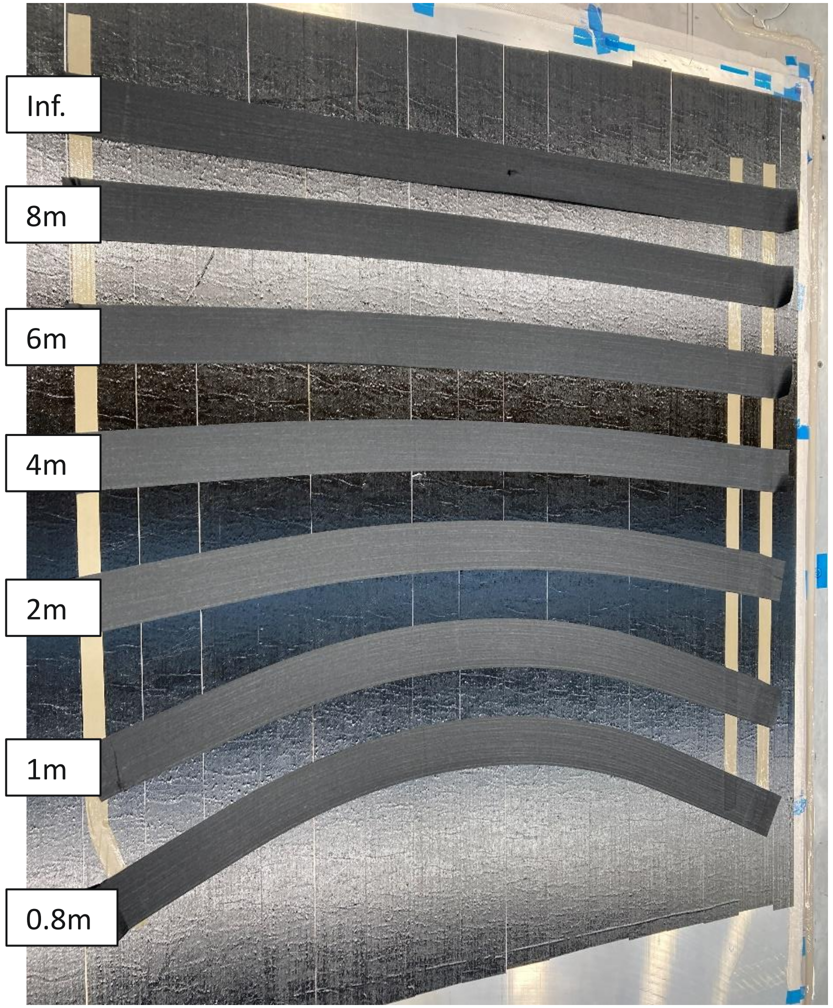
* inf. (i) damaged during KPV trials



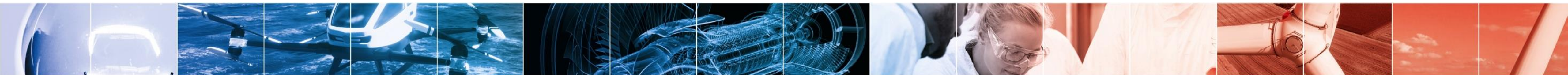
ATL AFFT R1 300623



ATL AFFT R2 030723

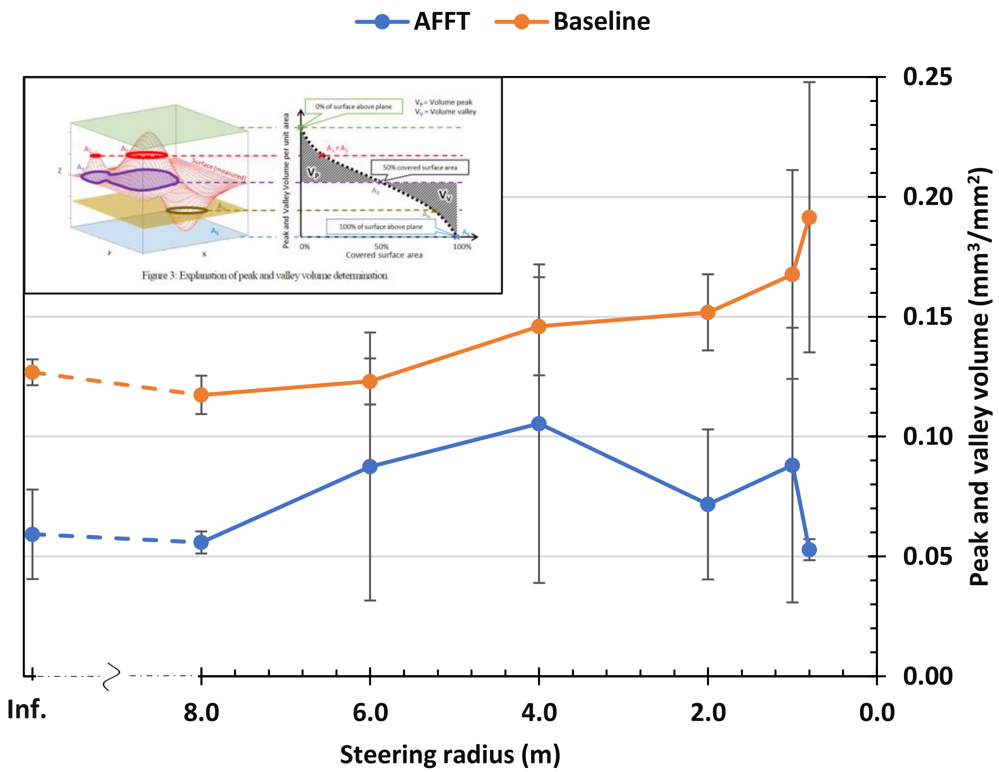


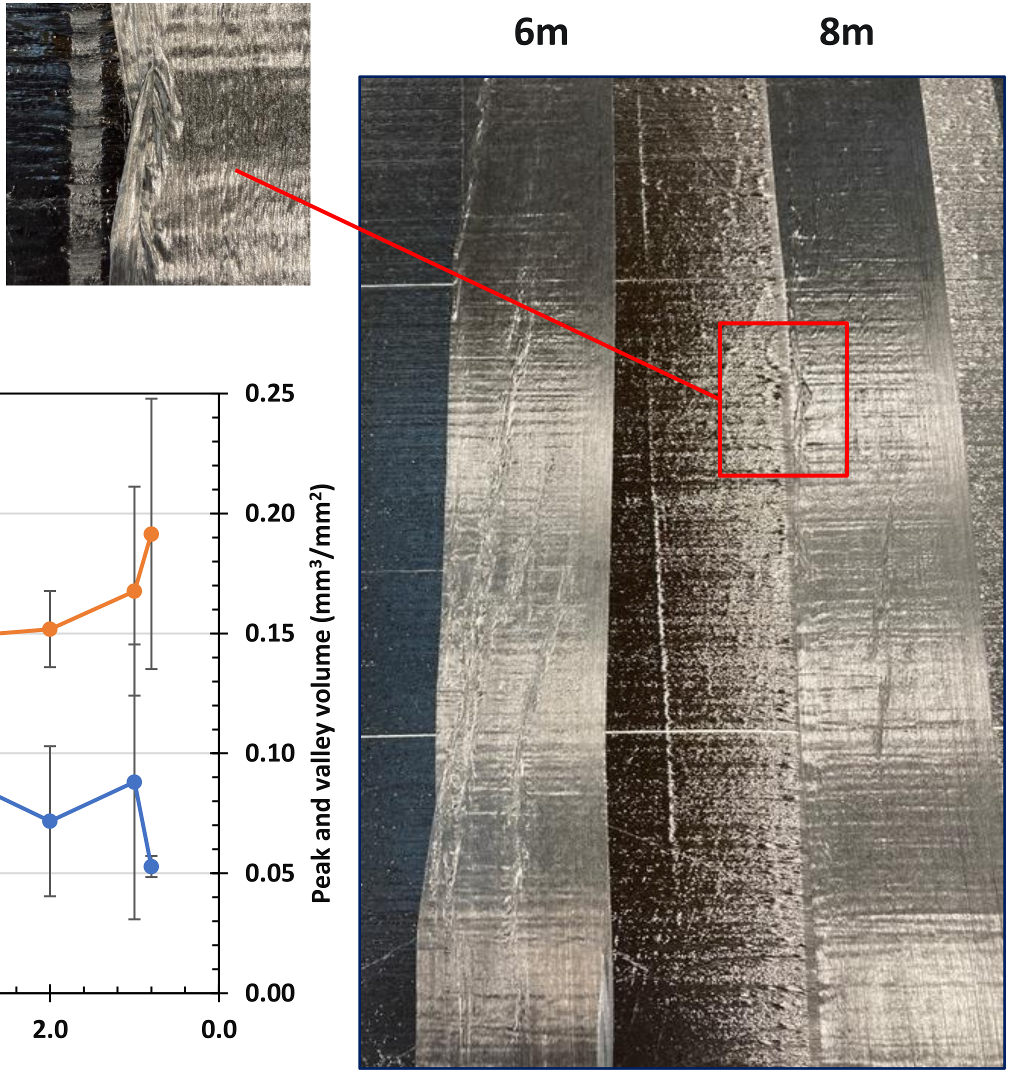
ATL AFFT R3 030723

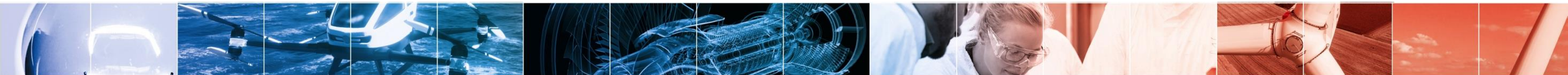


Critical steering radius

- Volumetric method: identify point at which the curve starts to increase rapidly
- Baseline begins increasing at 6m
  - ➢ Visual results indicate critical steering radius between 6 and 8m
- AFFT shows no clear trend
  - ➢ Visual results indicate critical steering radius < 0.8m
  - ➢ Initial preform (CSR= 2m) not scanned
- Error bars overlapping
  - ➢ Defects generally appear at tape end first, causing sample variation

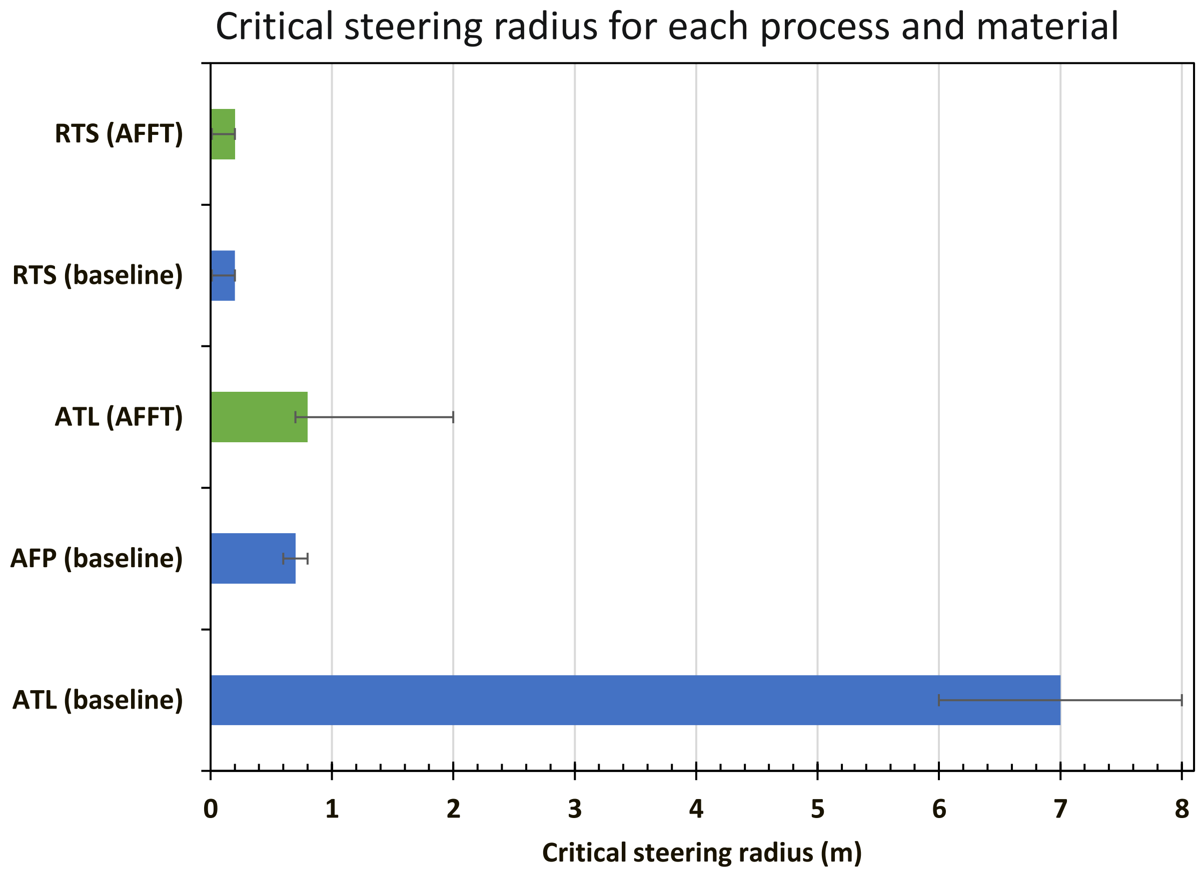


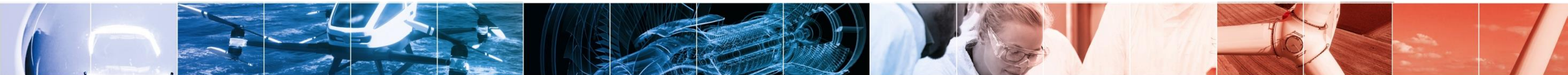


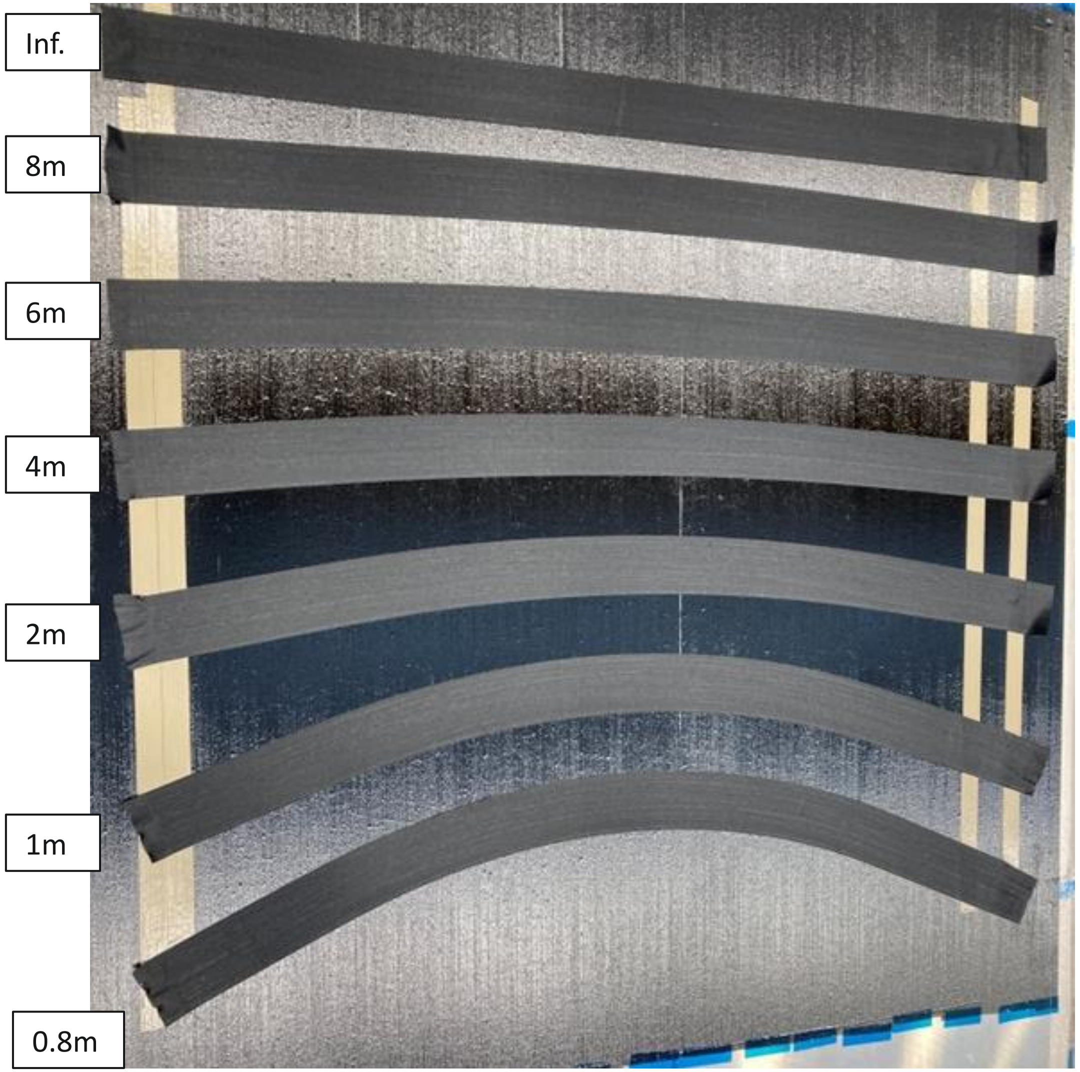


Conclusions

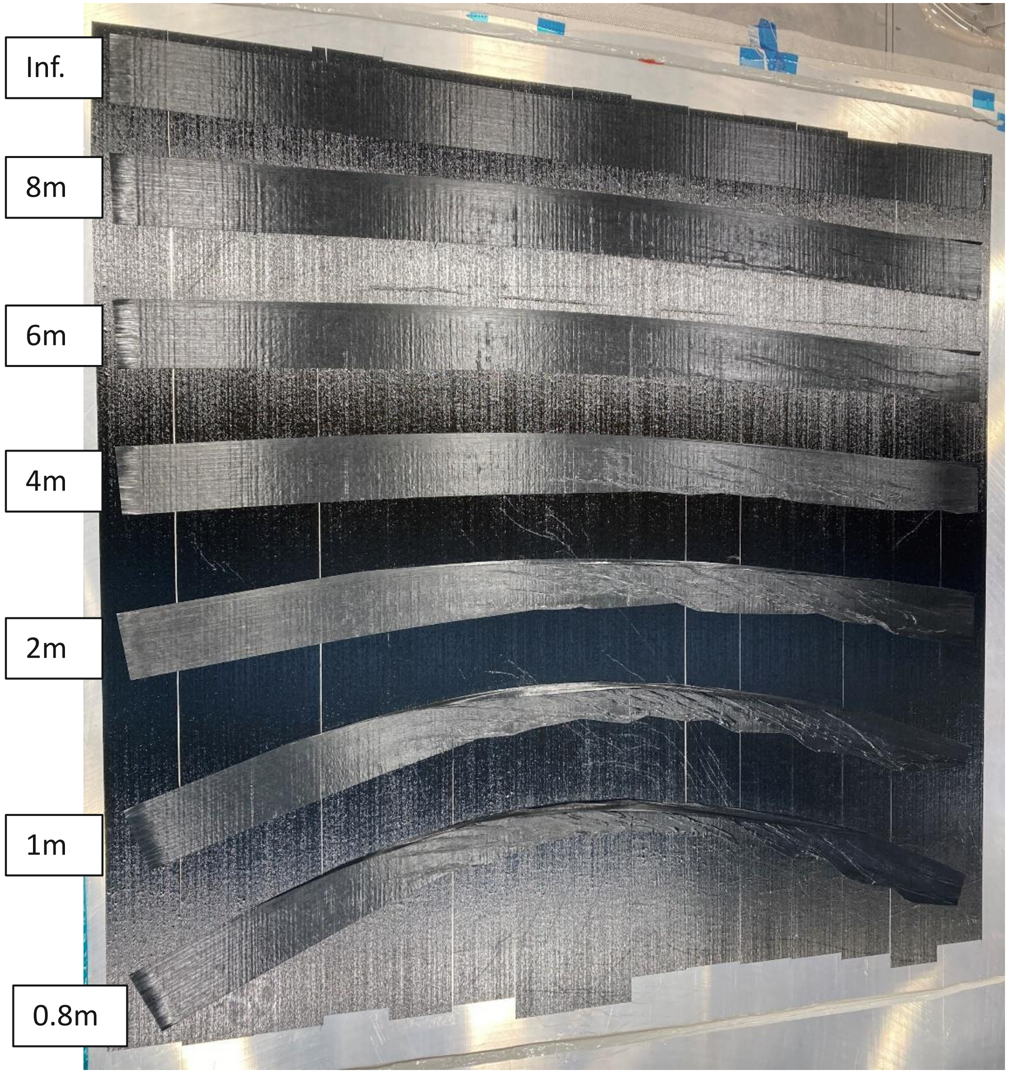
- RTS is much more capable than AFP or ATL
  - For both materials, **critical steering radius ≤ 0.2m**
- RTS enables more complex load paths for highly tailored structures
- AFFT outperforms traditional prepreg in the ATL trials, **critical steering radius approx. 0.8m + 1.2/-0**
  - Less material resistance to shear
- **If manufacturability is improved, AFFT material could be used in highly-tailored load applications, with high-rate deposition capabilities of ATL**







ATL AFFT steering map



ATL baseline steering map