Approach for investigations of progressive fatigue damage in 3D in fibre composites using X-ray tomography

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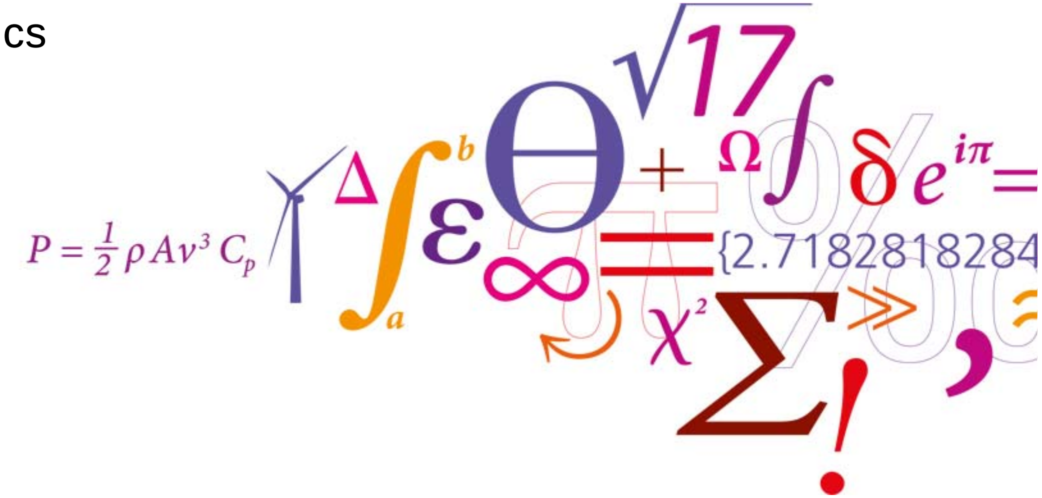

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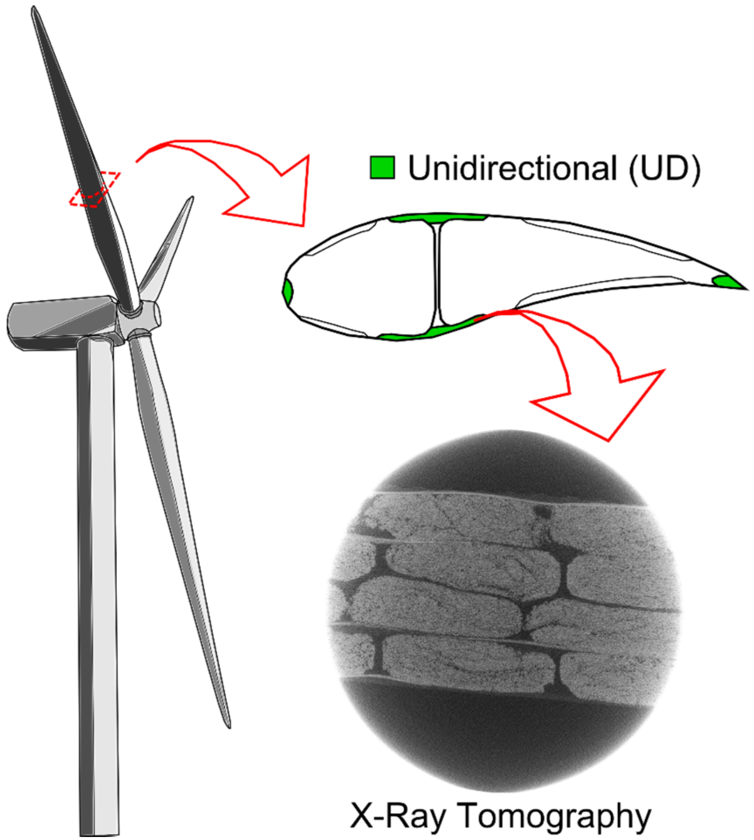
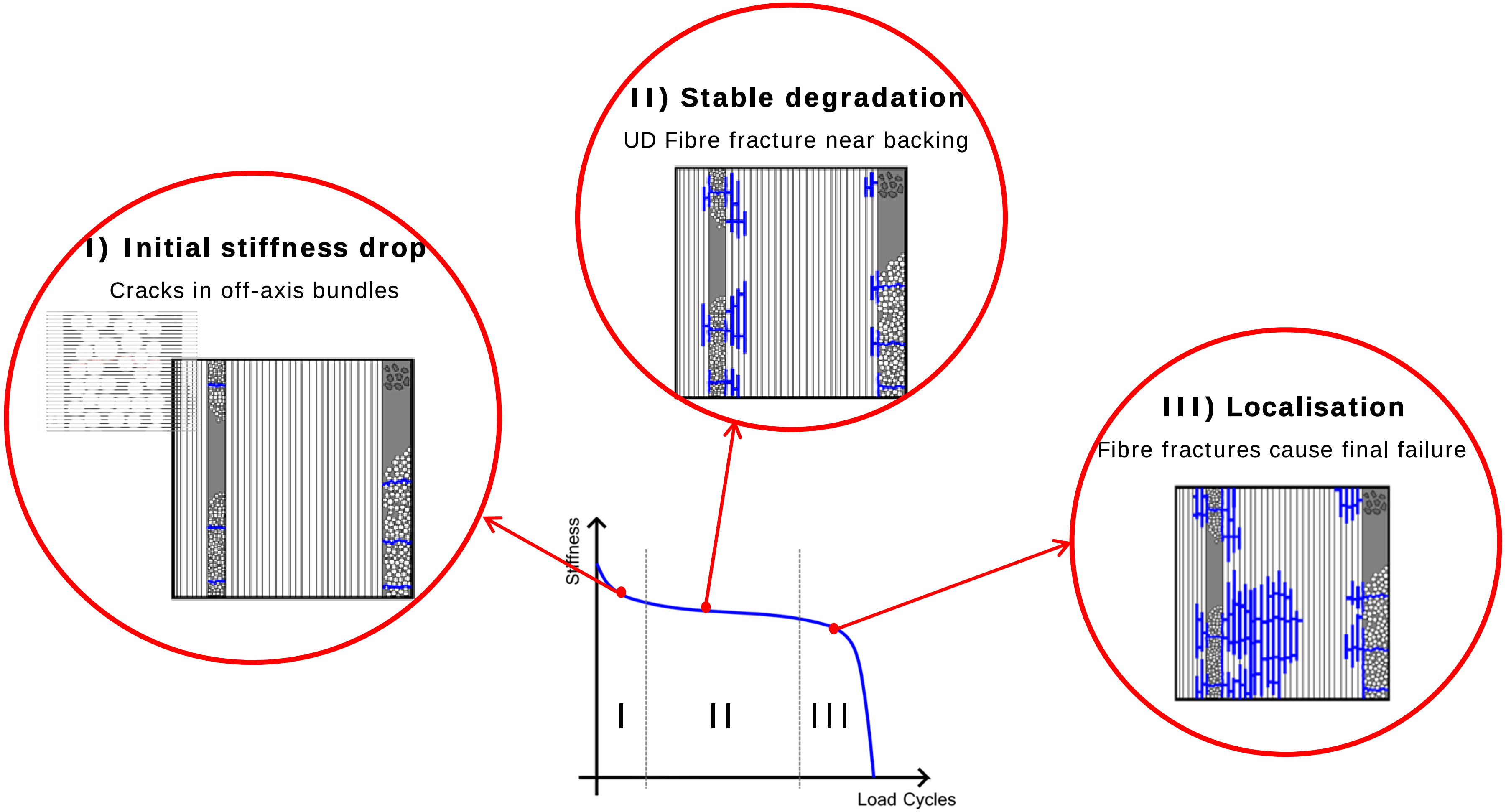
Fatigue damage evolution in fibre composites for wind turbine blades

- Why is fatigue a problem for wind turbine blades?
  - High number of load cycles throughout lifetime (~10^9)
  - Fatigue is one of the main limiting factors of designing longer blades
- UD NCF glass fibre composite used for wind turbine blades in parts carrying main bending load
- Fatigue in UD NCF composites is a mechanism not well understood



Fatigue damage progression for NCF UD

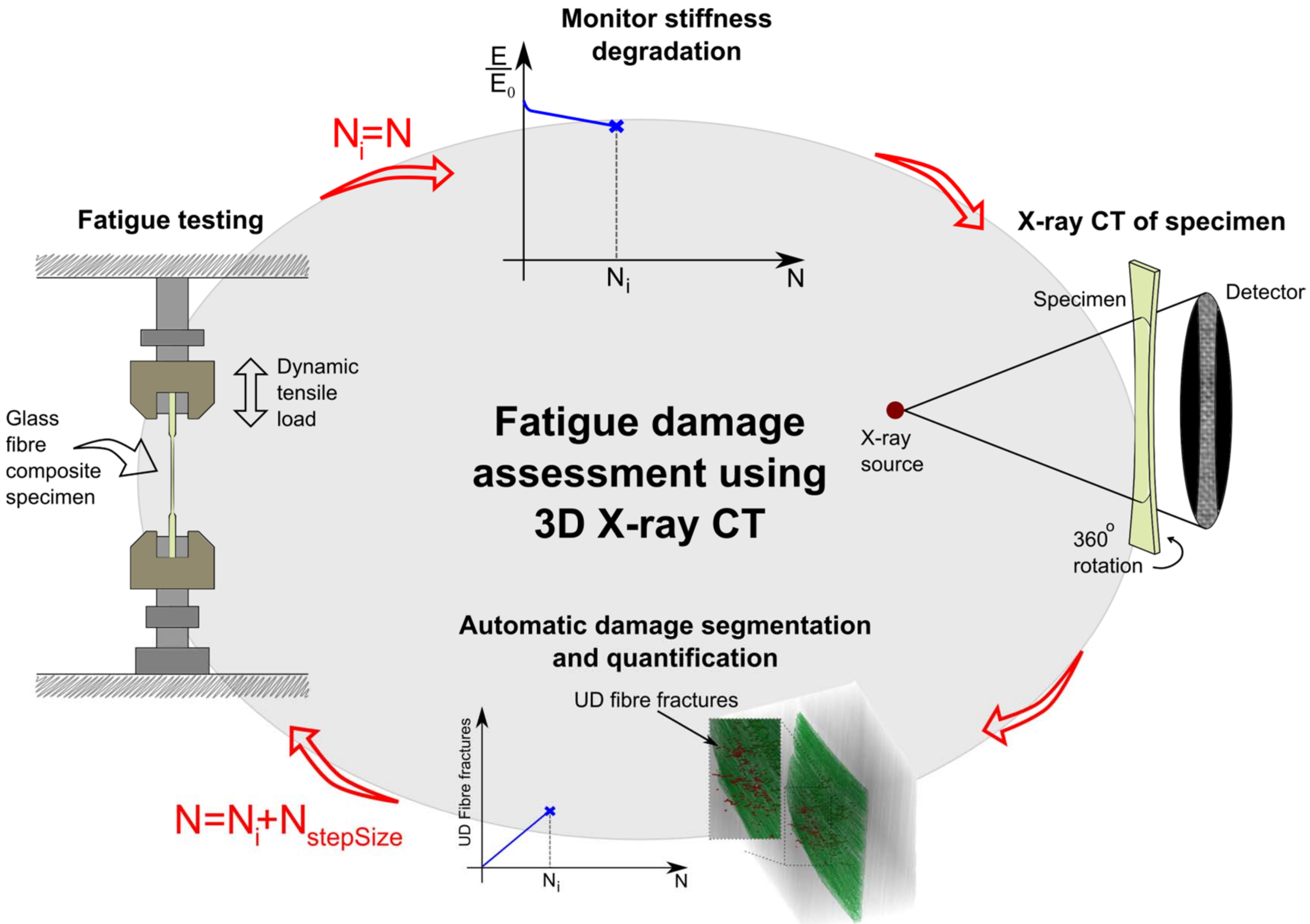
Fatigue damage hypothesis



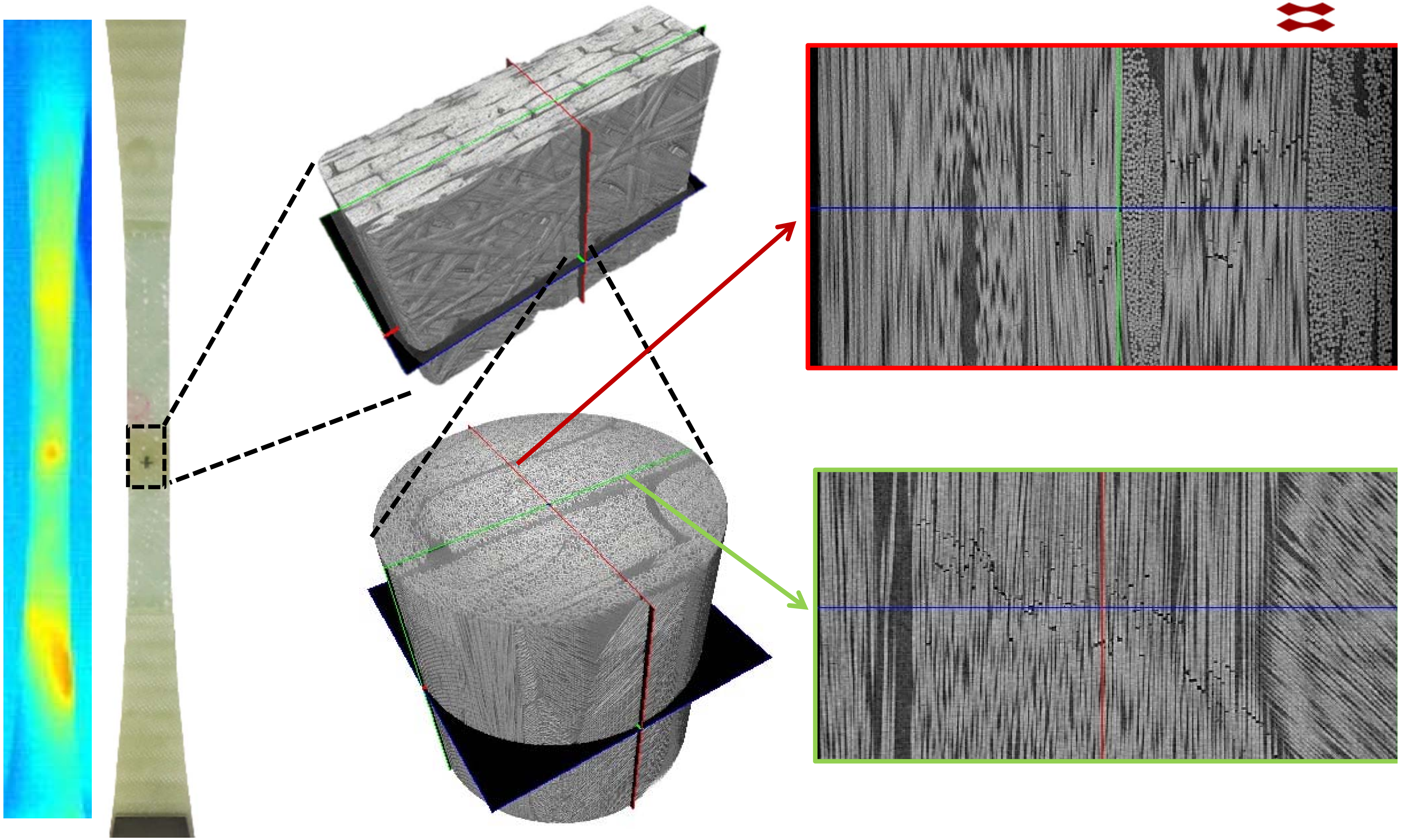
Ref: Jens Zangenberg, Povl Brønsted, and John W Gillespie Jr, 2013. *Fatigue damage propagation in unidirectional glass fibre reinforced composites made of a non-crimp fabric*, Journal of composite materials.

Experimental Fatigue Damage Assessment

Idea behind the method



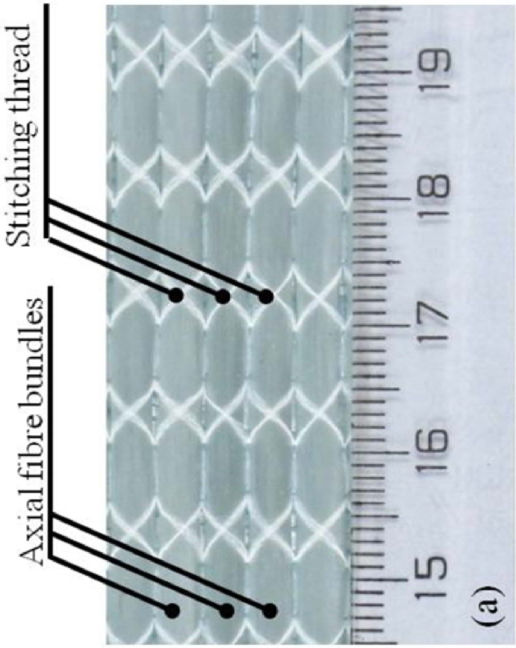
Fatigue damage evolution

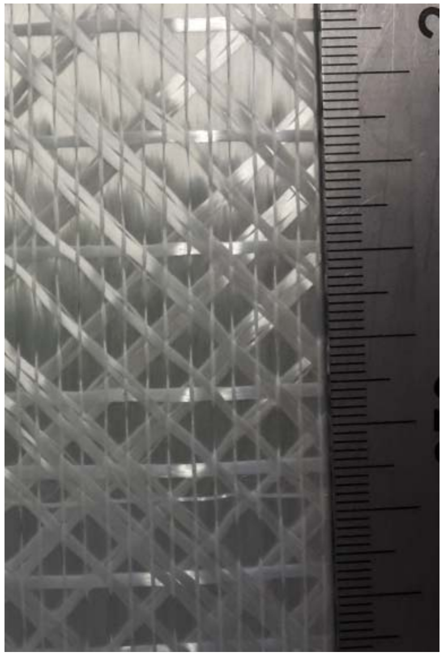


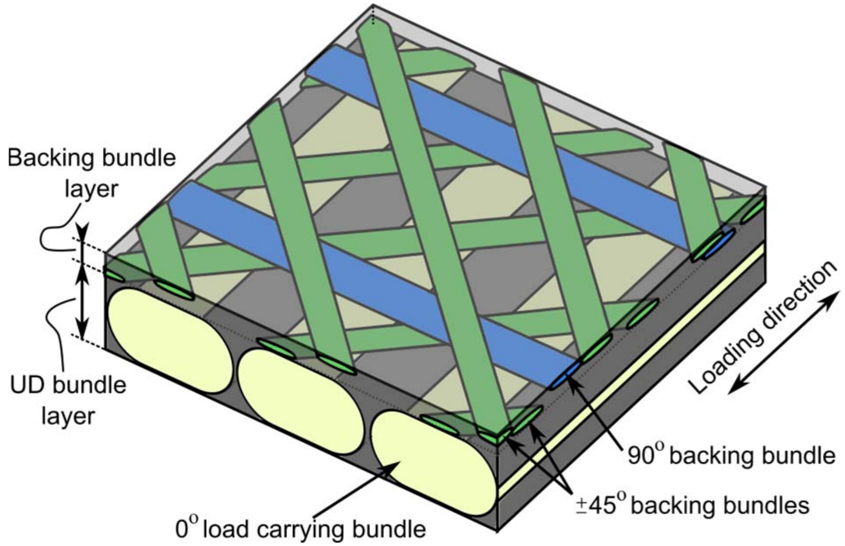
Non-crimp uni-directional composites for wind turbine blades

0: UD-side of non-crimp fabric

b_{45} : ±45,90 backing layer



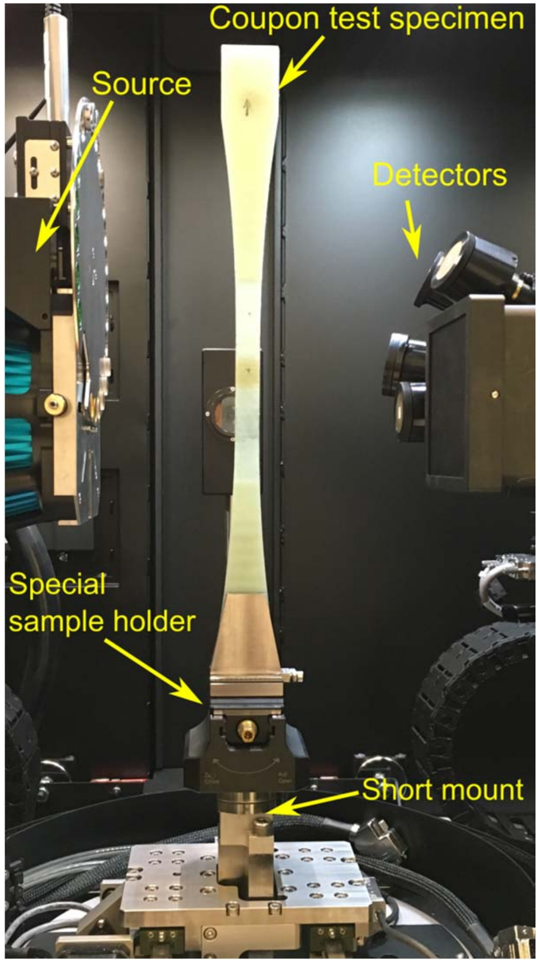




X-ray CT Experiments
Fitting large sample in CT scanner

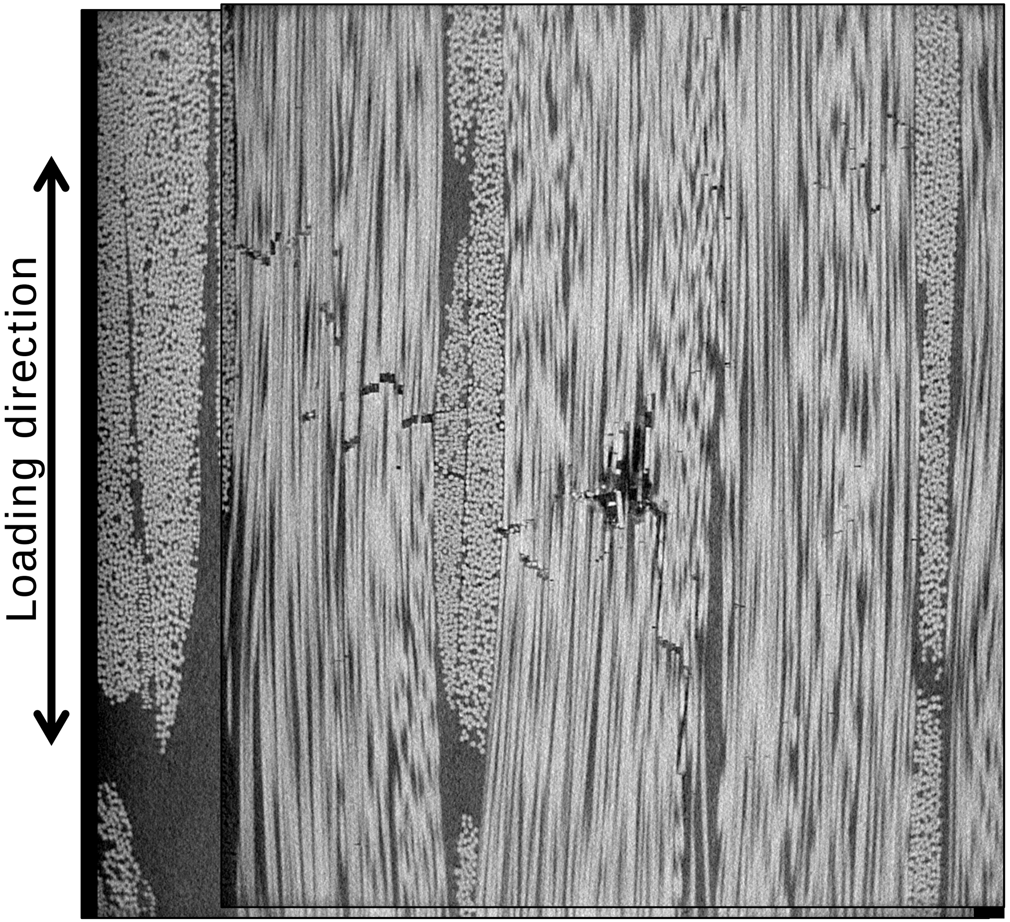
- Special sample holder and short mount was made in order to fit the **410mm long** sample in the scanner

- Using this sample holder, it is possible to mount the sample in the same way at every interruption point with only a small variation.

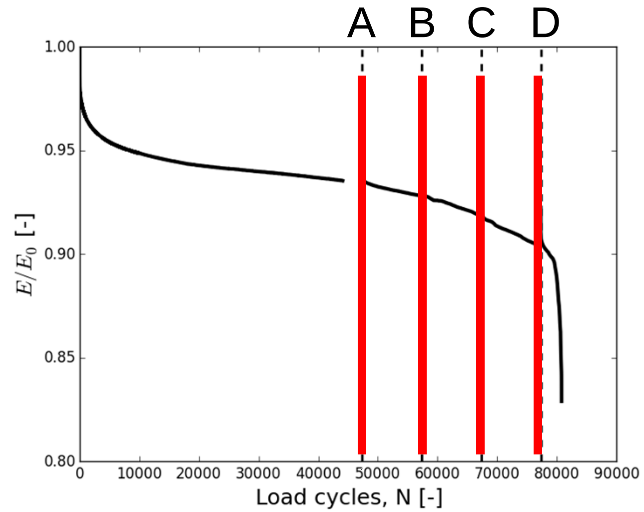


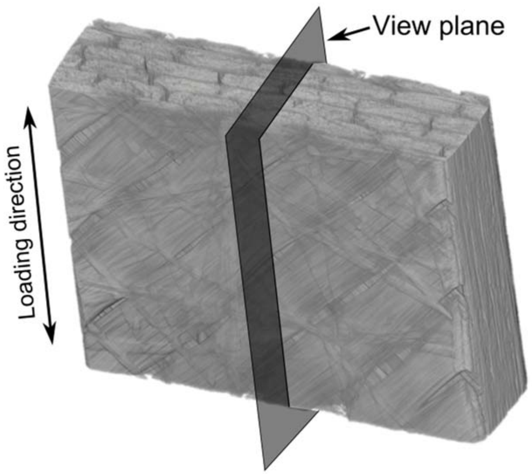
m1.1 stress rig for fatigue testing (M12)

Ex-situ X-ray CT results

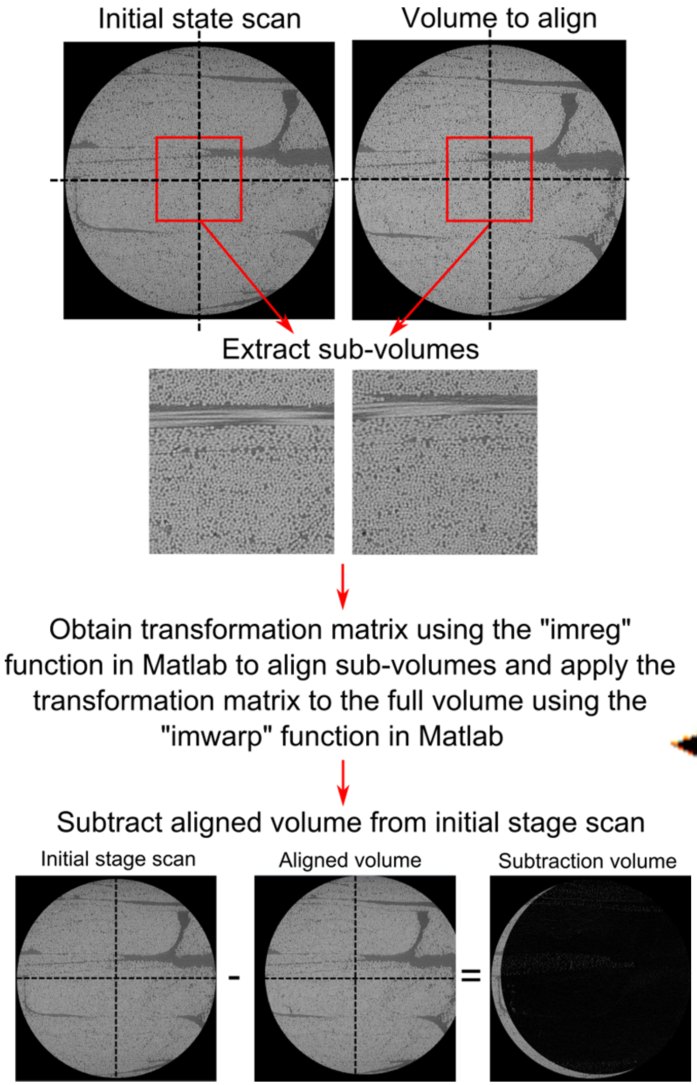


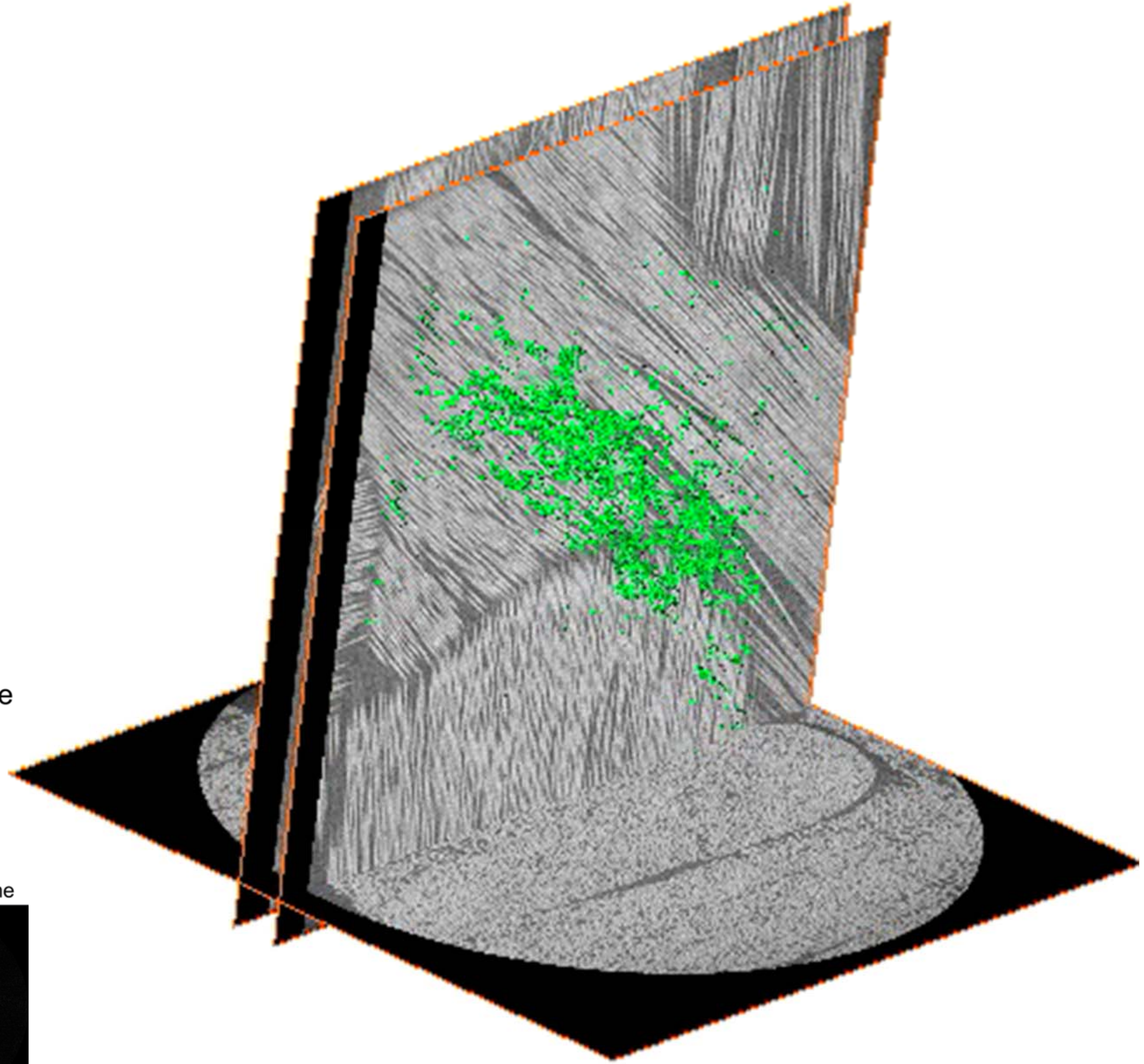
B: 57300 cycles





Segment out the fiber failure





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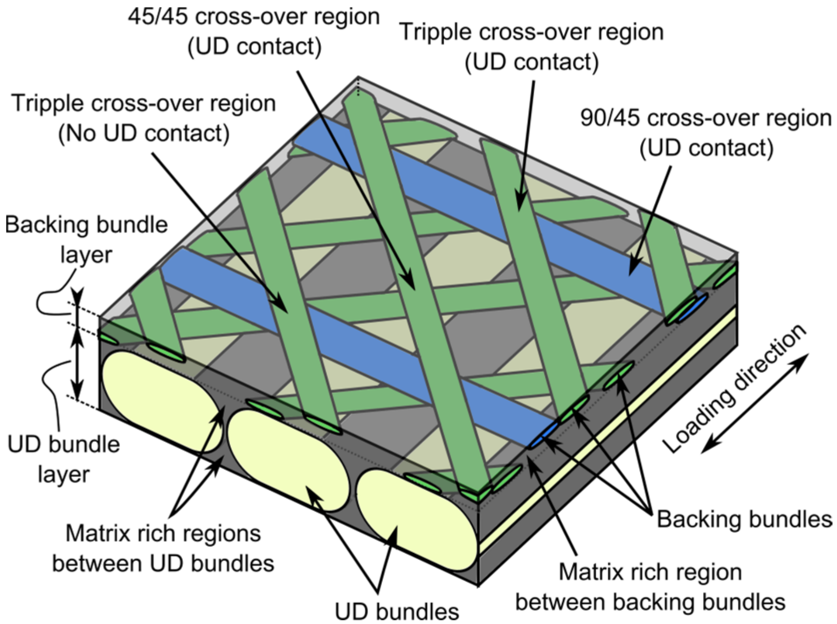
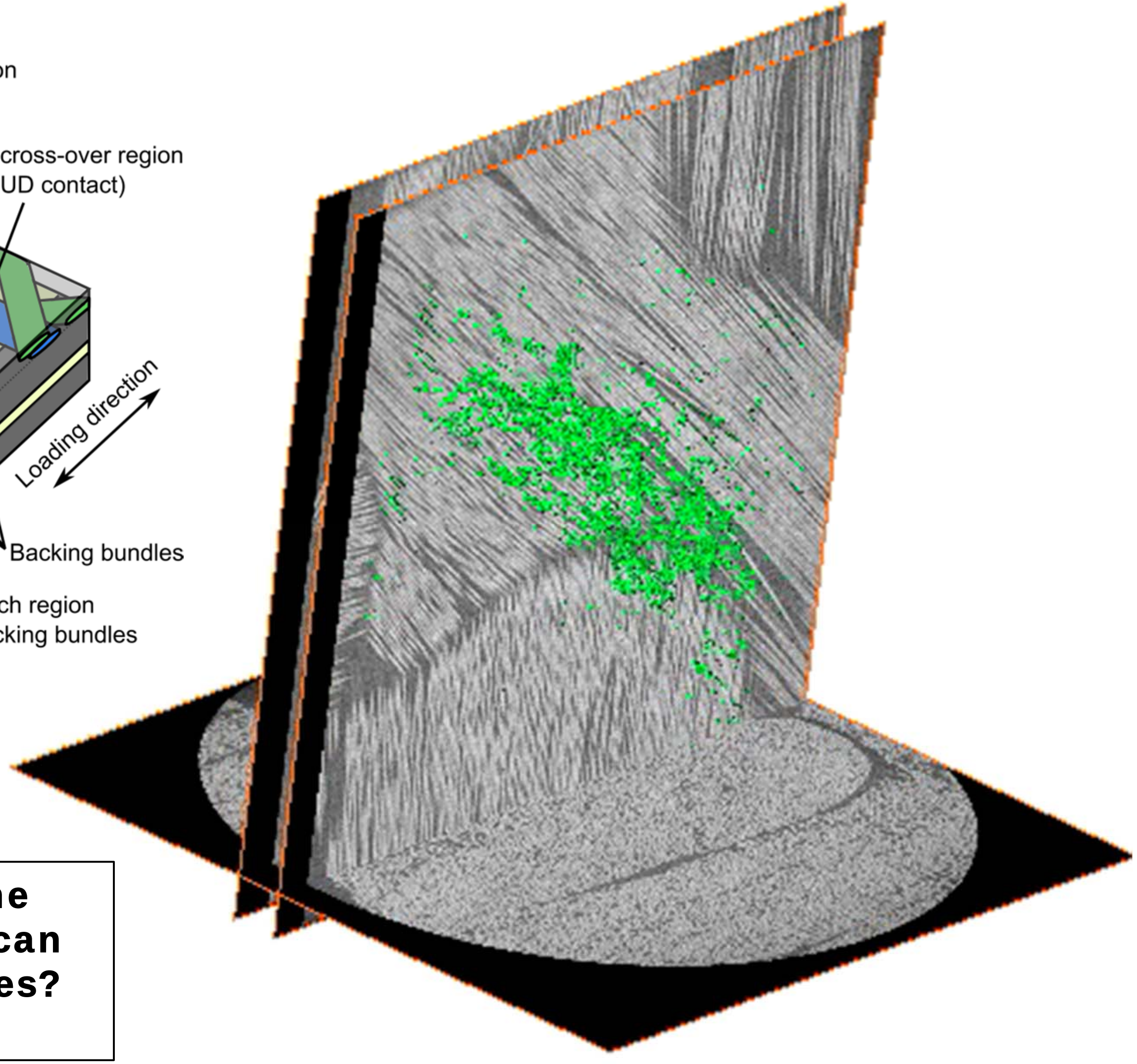
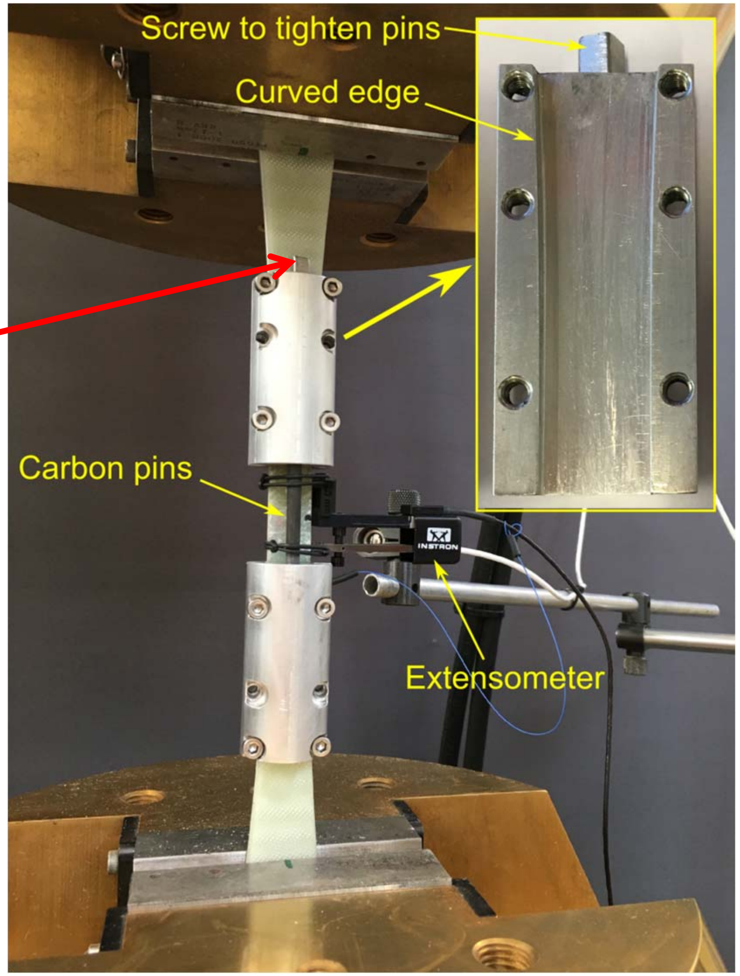




Gives good knowledge on the progression mechanism, but can we see all the damage features? Cracks might be closed.

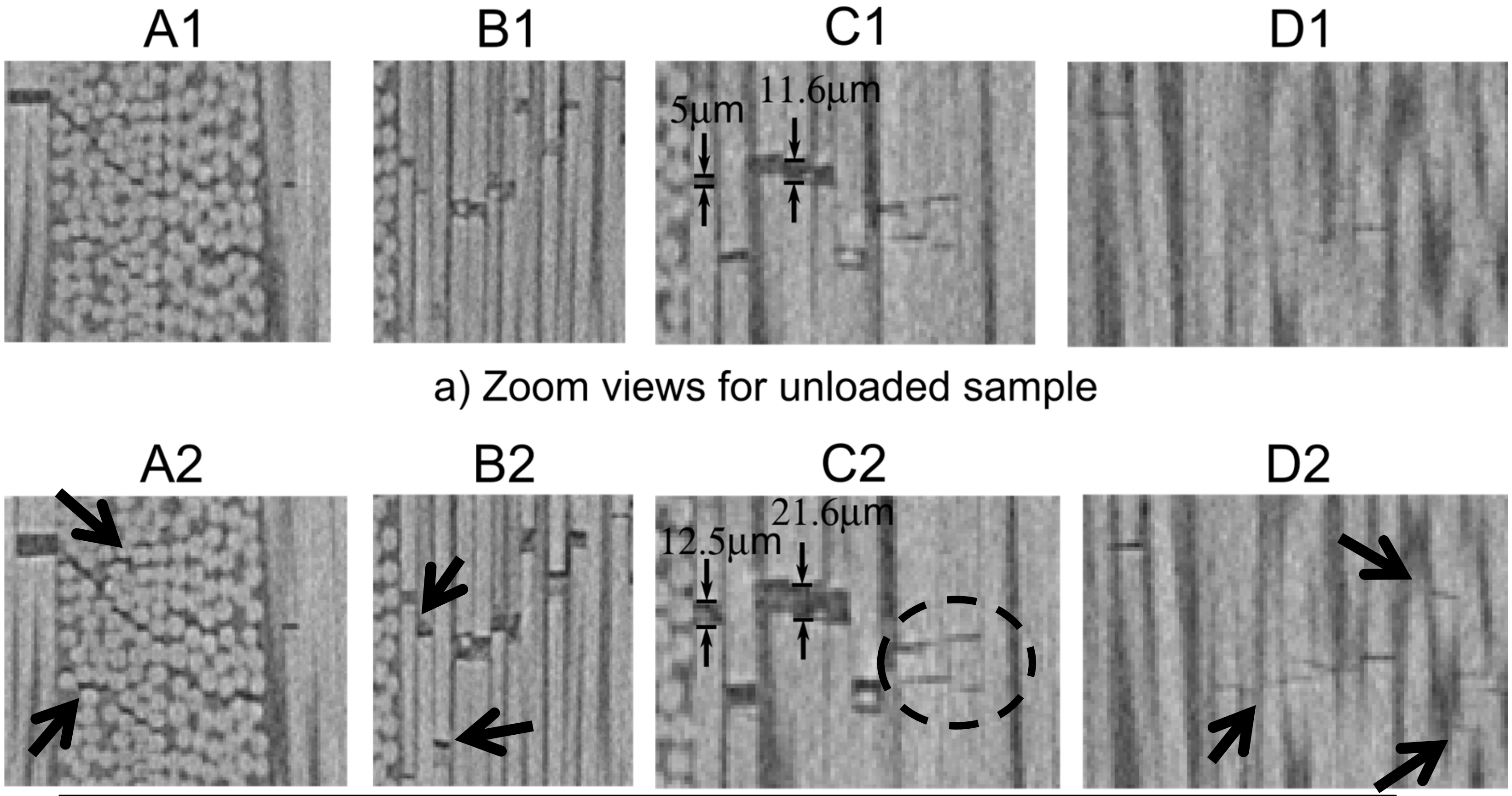
Applying tension to the sample during scan
Applying load (outside scanner)

- Sample loaded in tensile test machine outside scanner and clamp is attached
- The clamp utilizes the curved specimen geometry for load transfer
- Carbon pins are tightened by screw while sample is loaded
- Load on the sample is released and the carbon pins keep the gauge region in tension.
- Using this solution it was possible to keep the sample at 0.17% strain (around 3-4kN) during scanning



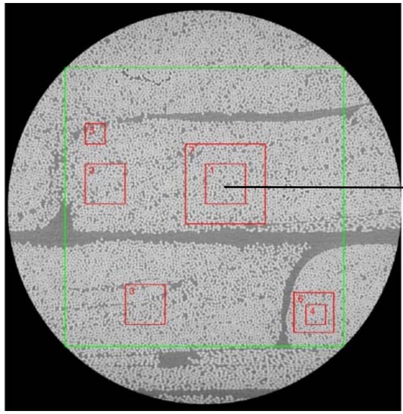
Applying tension to the sample during scan

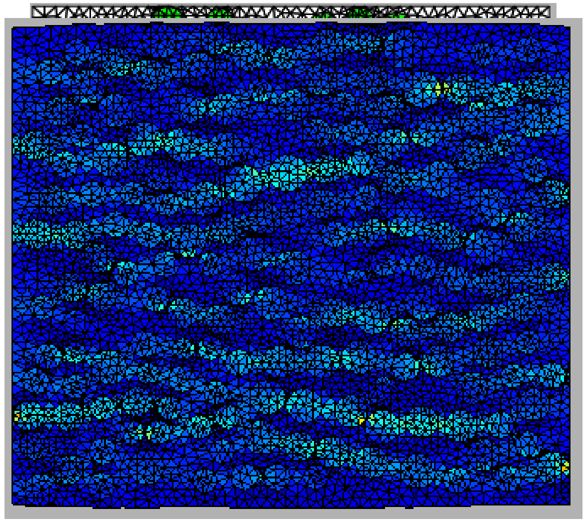
Results, zoom views

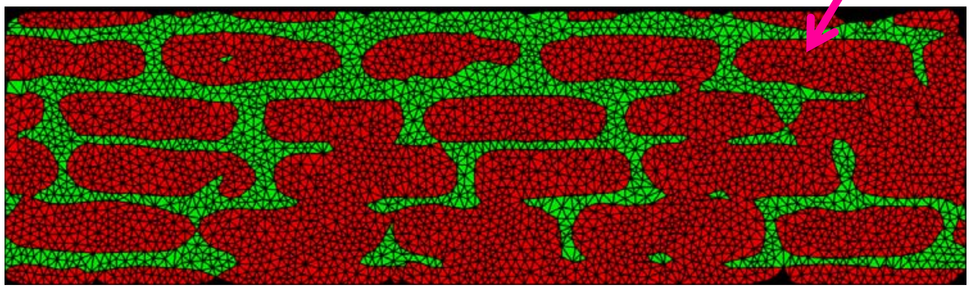


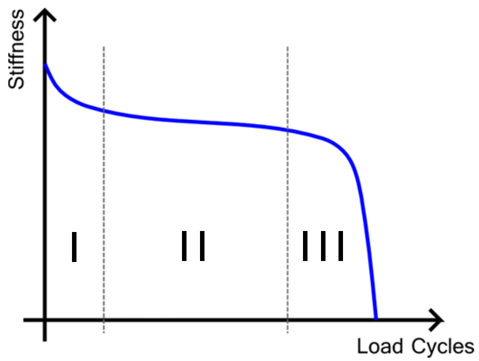
Additional fibre fractures appear and off-axis cracks become more visible when applying tension during scanning. Applying a higher load is likely to have a more pronounced effect

Micro-mechanical modeling (Multiscale)









PhD summerschool and E-learning: CinemaxII

Multi-scale modelling: Understand stiffness drop and cure dependency of fatigue

Conclusions

- Location for fatigue damage was identified near backing bundles and typical at location with intertwining bundles
- Postulated fatigue damage evolution starting as transverse cracking in the backing bundles and subsequently spreading into the load carrying uni-directional fibers
- Fatigue damage evaluation was observed during non-destructive ex-situ X-ray CT scans
- Since the damage is observed in 3D, manual quantification is cumbersome and therefore work is ongoing on automatic UD fibre fracture quantification by image analysis.