Wind Energy Denmark 2019:
Test innovation needs for large blades

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Head of Structural Design & Testing team

Full scale test of very large blades

- Will it make sense to test a 200 meter blade in the same way as we do today?
- What will it cost and how long time will it take?

- At which blade length will it stop to make sense?
- What is the maximum test time we can accept?

- Shall we then test blades in a different way?
- Is there a different path to go?
- What should happen before we can rely on computer simulations only?
- How can we verify and get confidence in our numerical structural models?

Blade	Natural freq.		Test time
length	flap	edge	days
86,4	0,61	0,93	167
100,0	0,5	0,75	205
120,0	0,41	0,61	251
150,0	0,32	0,47	323
200,0	0,23	0,33	453

Recent results towards more realistic testing of wind turbine blades – BLATIGUE project

Oscar Castro, Federico Belloni, Peter Berring & Kim Branner
DTU Wind Energy

BLATIGUE - Fast and efficient fatigue test of large wind turbine blades

A project supported by EUDP and VILLUM FONDEN

Project partners:

- DTU Wind Energy
- Siemens Gamesa Renewable Energy A/S
- R&D A/S
- Blade Test Centre A/S (BLAEST)
- Olsen Wings A/S
- DNV GL
- Zebicon A/S
- Ørsted A/S

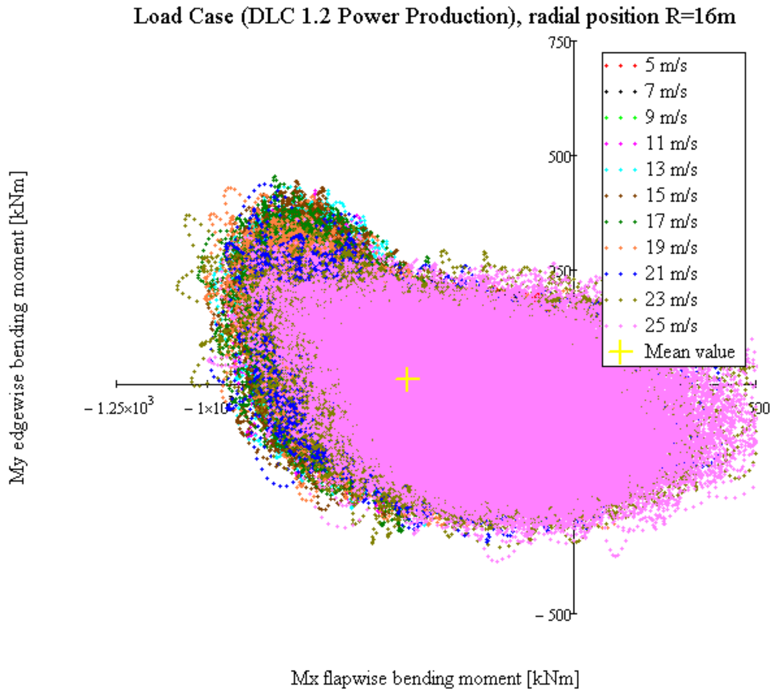
The objective of BLATIGUE is to develop **fast and efficient fatigue test methods** for large wind turbine blades and to develop **equipment to excite the blades** under such tests.

- Period: Dec. 2016 – May 2020
- Total hours: 30730 h

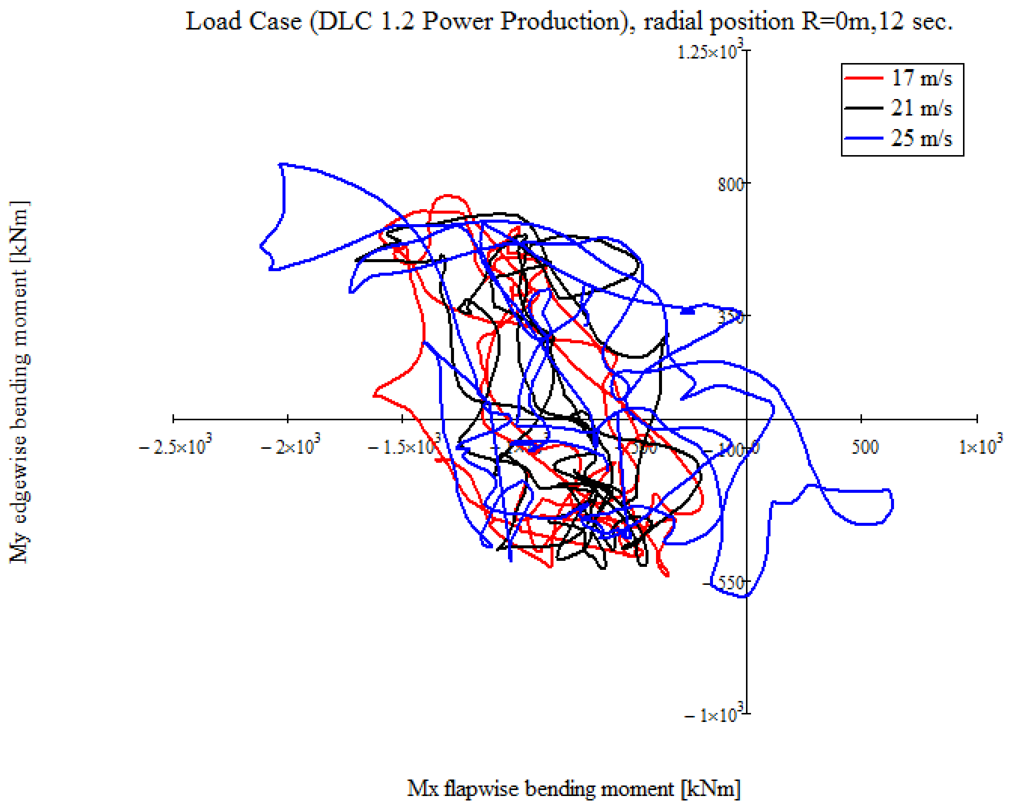
Energiteknologisk udvikling og demonstration

Fatigue testing

- According to IEC61400-23 blades shall be tested in fatigue:
  - In flapwise direction
  - In edgewise direction



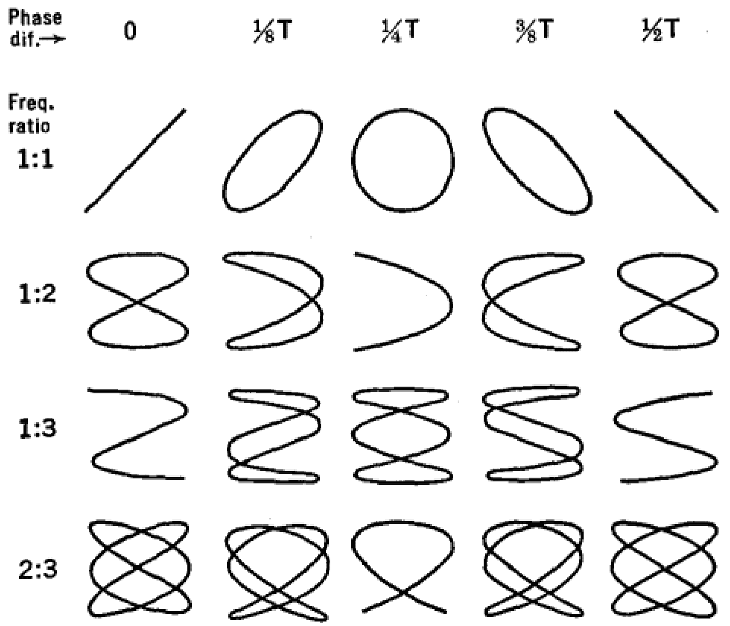
Complete load cloud at the SSP 34m blade cross section at R = 16m



A 12s sample of load cloud at 17m/s, 21m/s and 25m/s at the SSP 34m blade root section

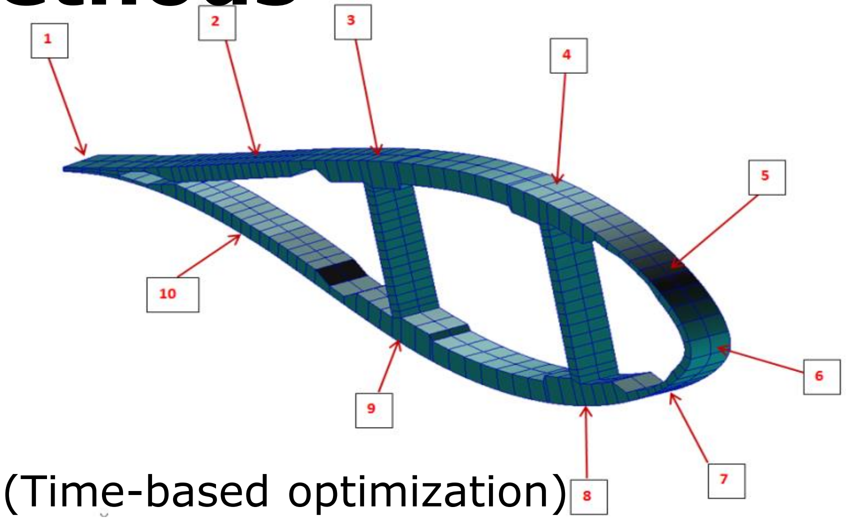
Development of multi-axis test methods

- Development is so far done on 14.3 m blades from Olsen Wings
- Different excitation methods used:
  - Single axis
  - Chaotic
  - Lissajous curves

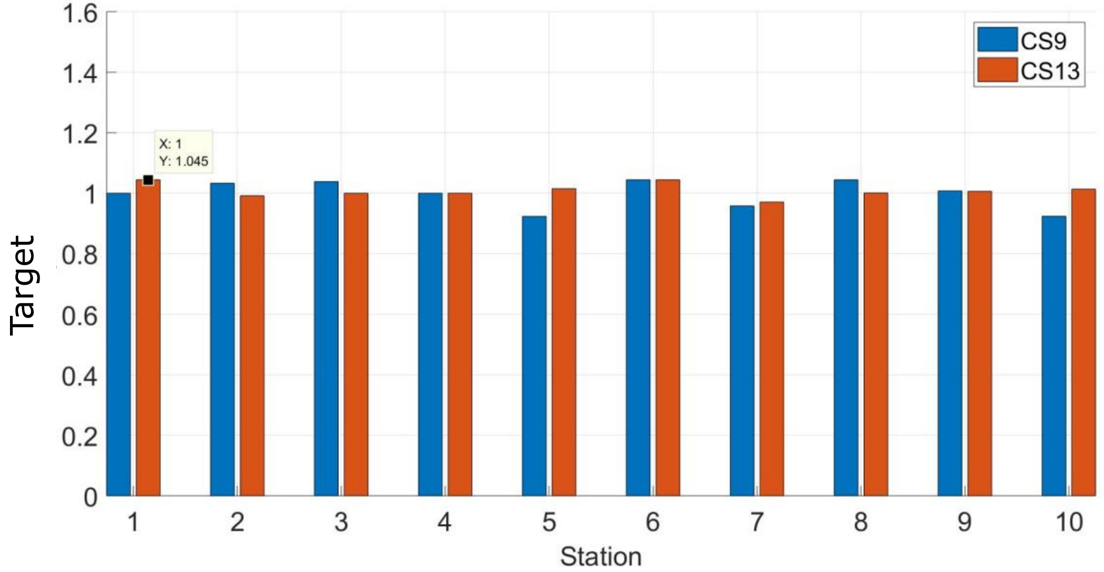


Development of multi-axis test methods

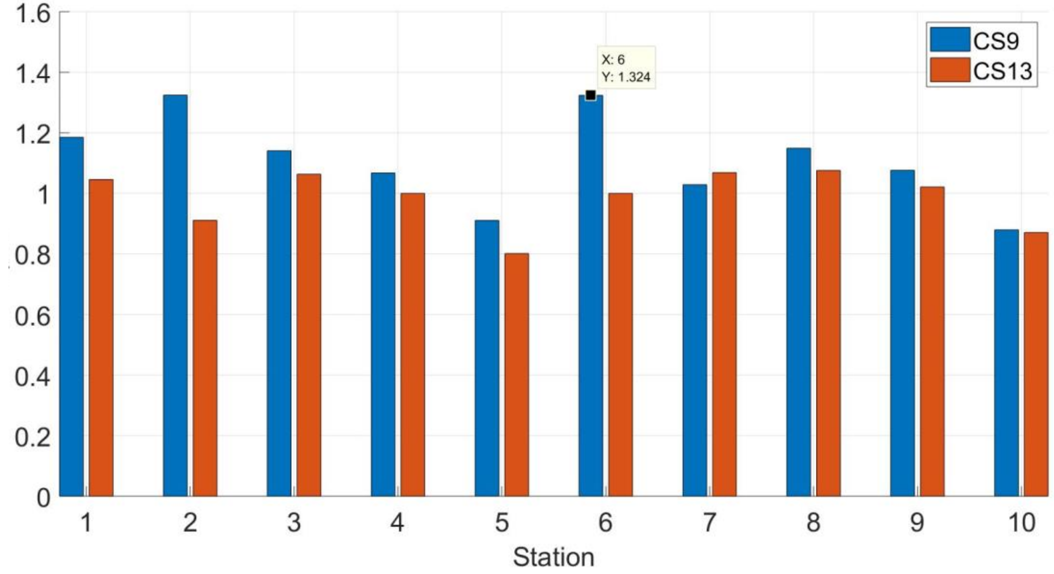
- Two cross sections are considered:
  - CS9 (42% from root)
  - CS13 (63% from root)
- Optimization is used to meet the targets by combining different fatigue test methods in the most efficient way.



Error-based optimization

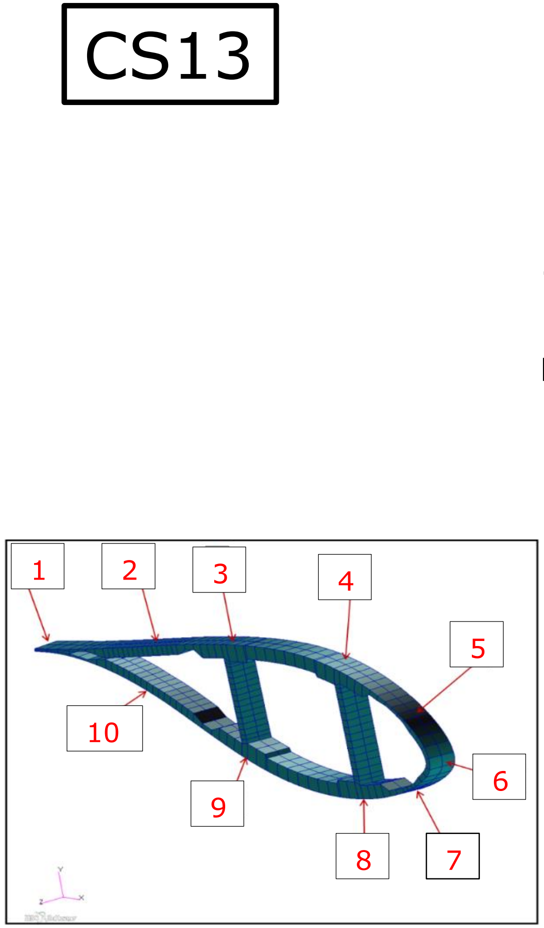


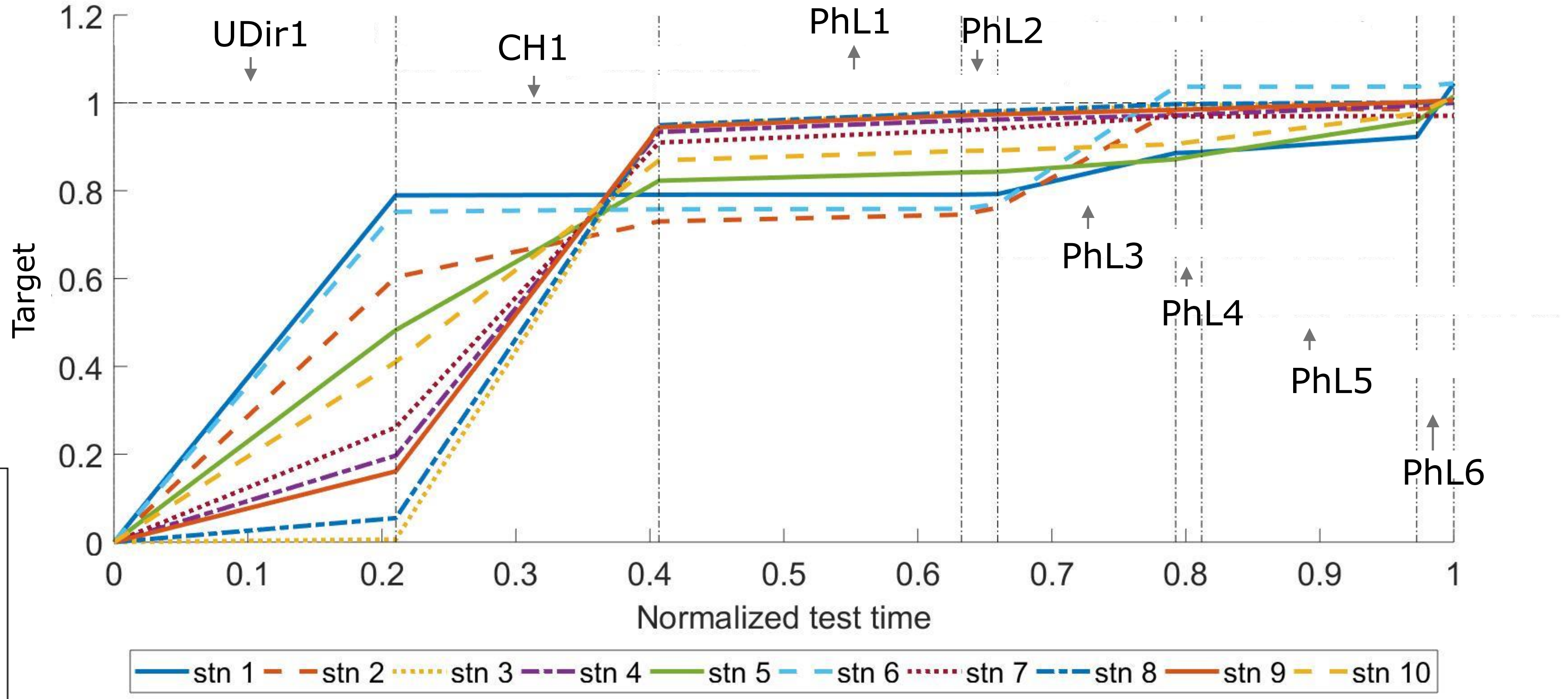
Flap + Edge (Time-based optimization)



All combined cases

Load contribution - Error-based opt.





Conclusions

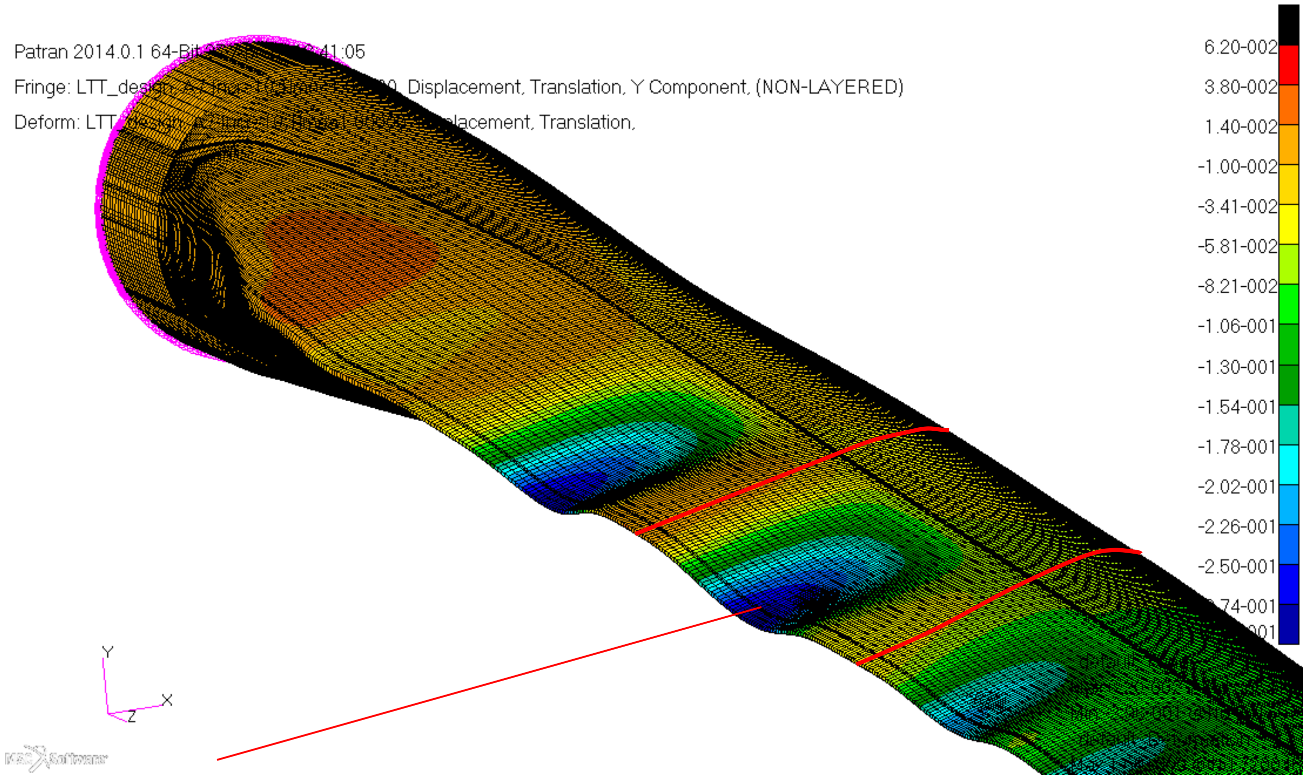
- Work in progress
- Method will be published soon
- Method still to be demonstrated in blade test lab

- Vision is to develop a fatigue method that is both faster and meet fatigue targets much more accurately
- It is uncertain how fast it can be without being too “wild”

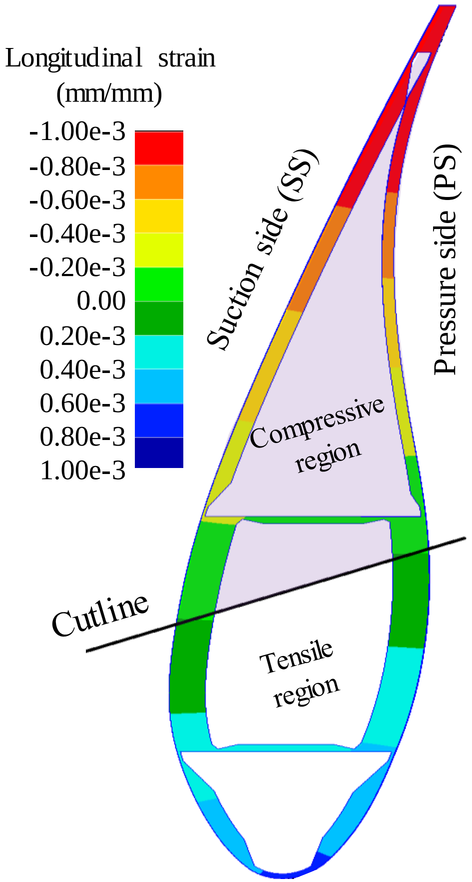
A way to verify and get confidence in our numerical structural models

Xiao Chen, Peter Berring, Kim Branner, Steen Hjelm Madsen,
Sergei Semenov & Federico Belloni
DTU Wind Energy

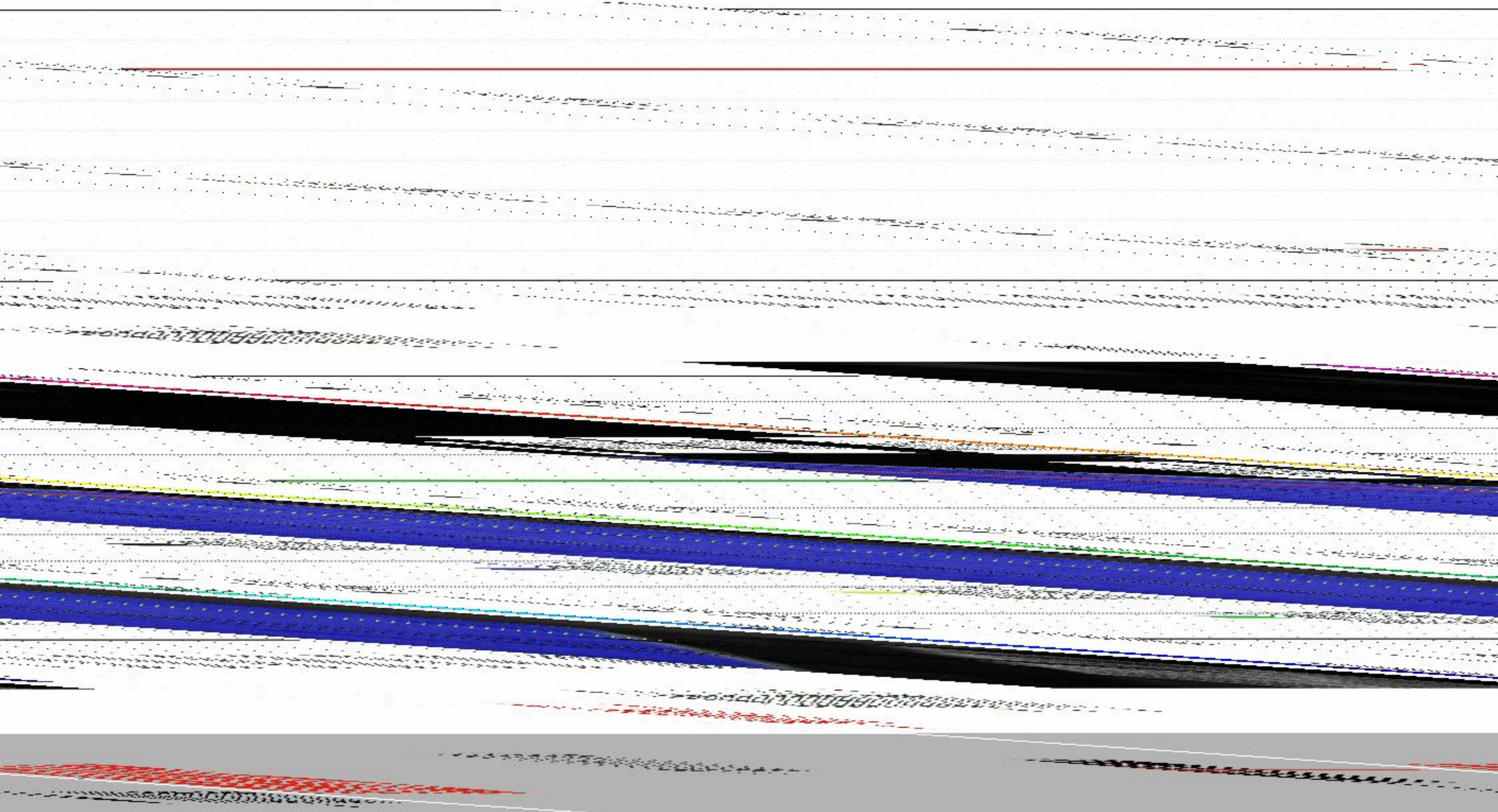
Cutting the subcomponent from the blade



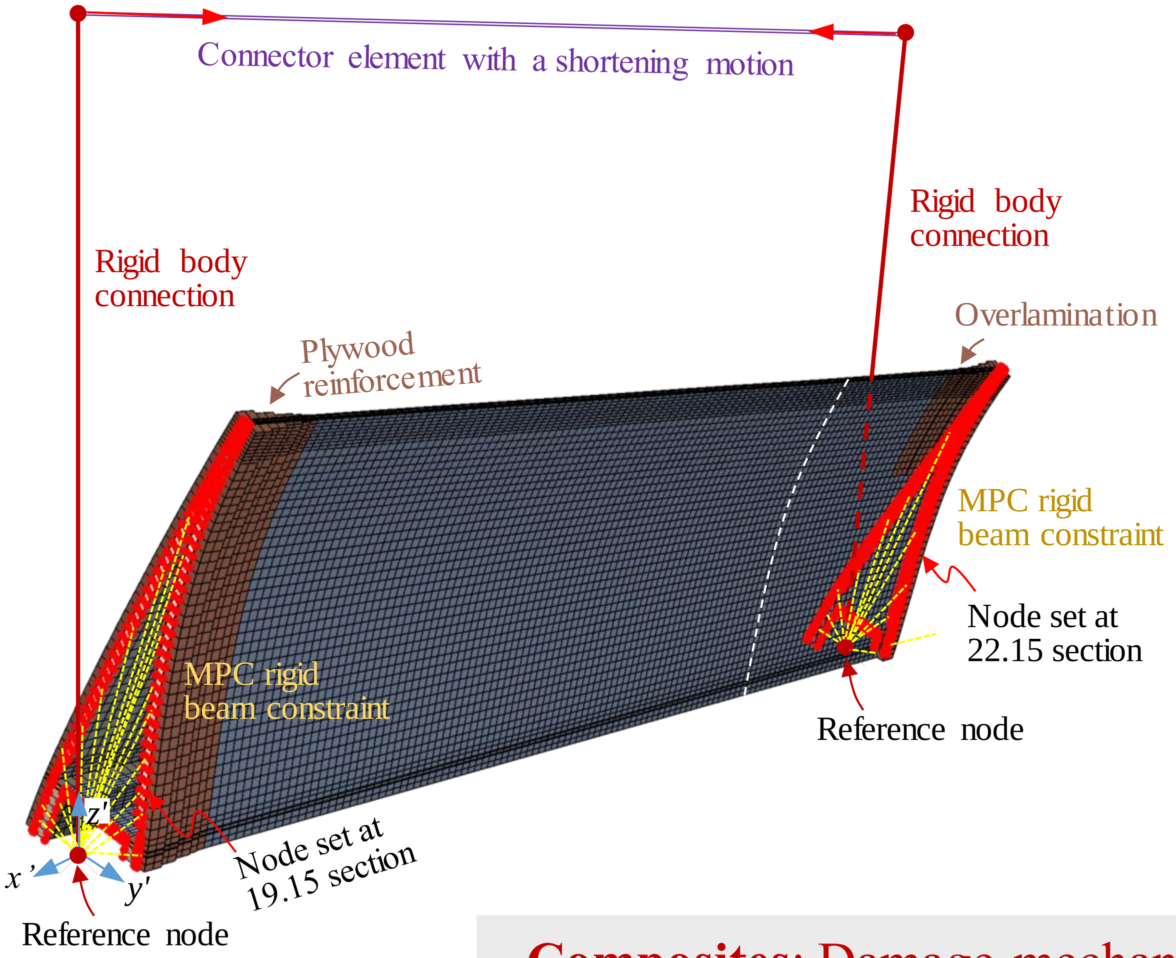
Waves/buckling are observed along the trailing edge

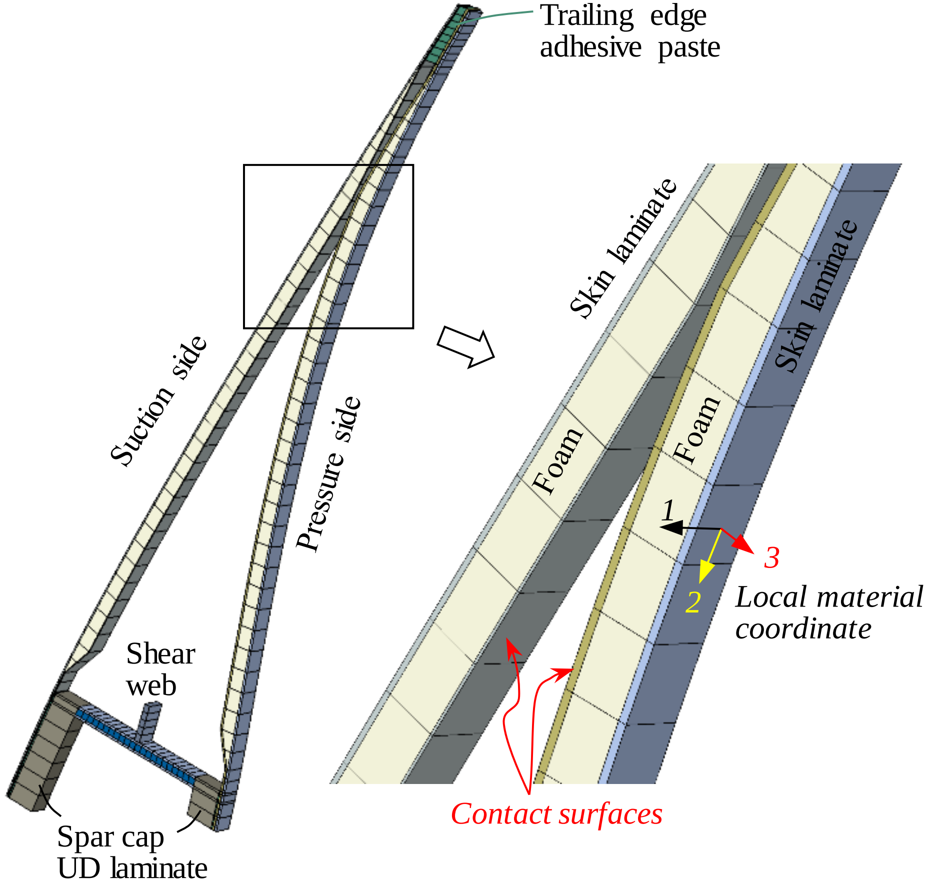


Trailing edge subcomponent with plywood reinforcement



FE Modelling with multiple material failures





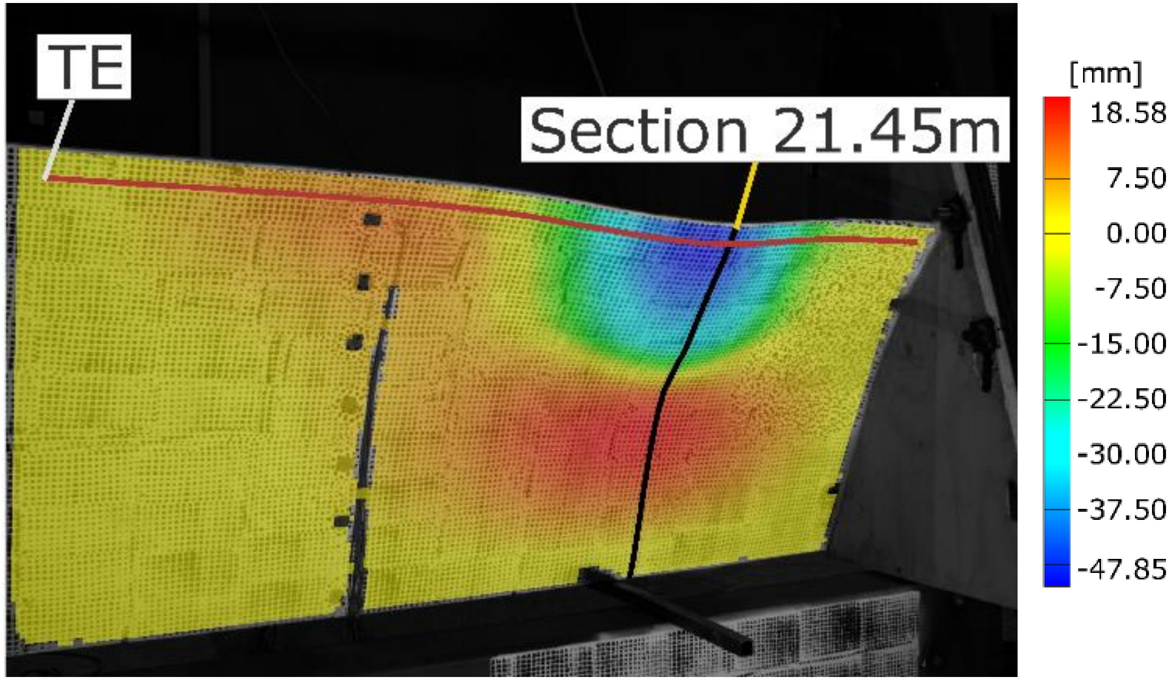
Composites: Damage-mechanics based progressive failures

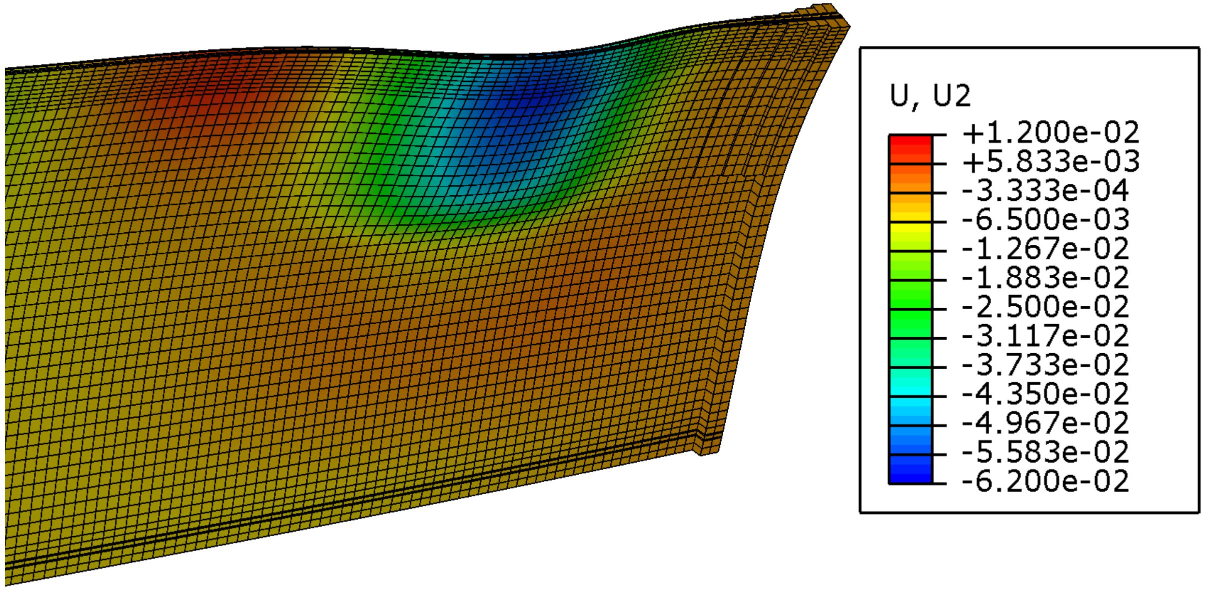
Foam core: crushable failure with elastic and plastic behaviour

Adhesive paste: cohesive elements traction-separation law

Comparison between DIC measurement and FE simulation

Out-of-plane deformation in the post-peak regime



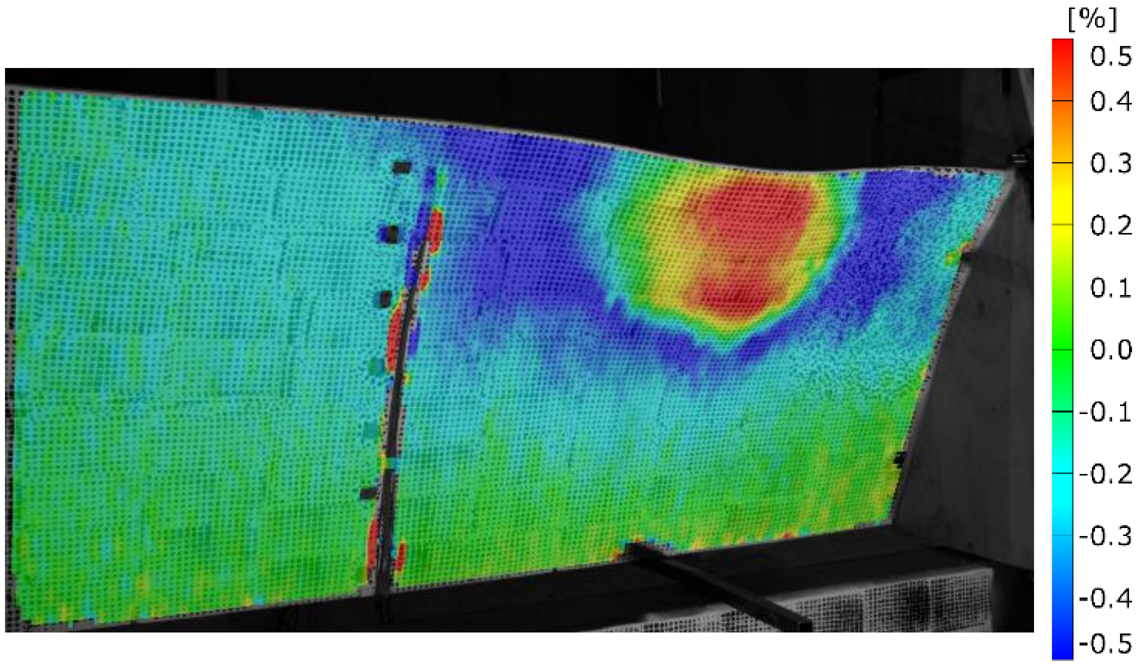


DIC measurement

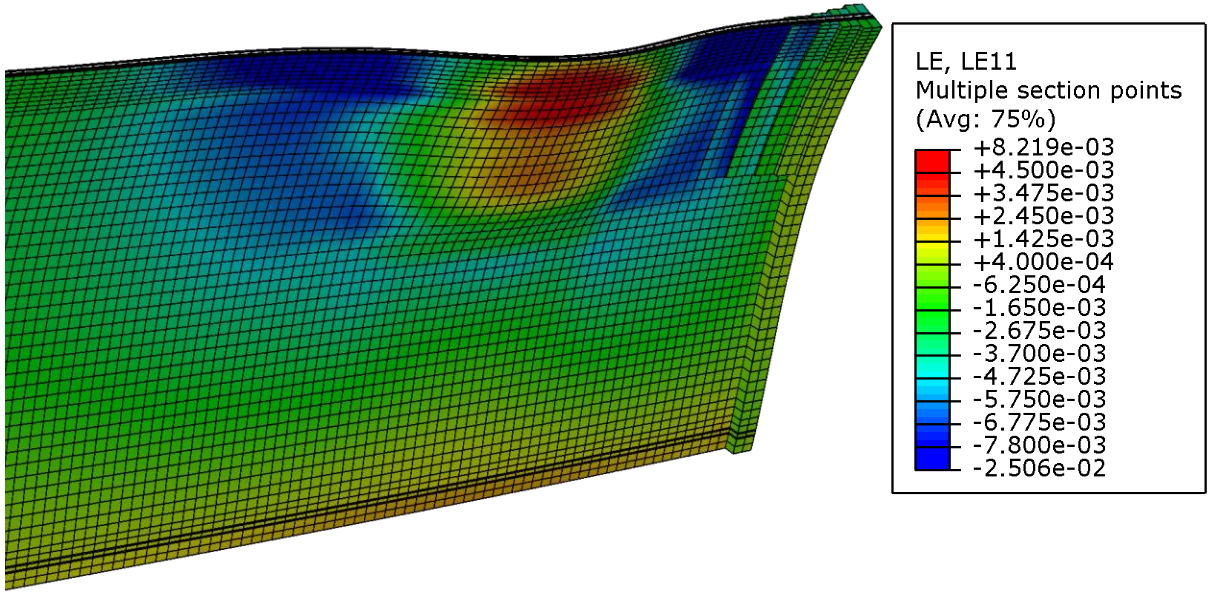
FE simulation

Comparison between DIC measurement and FE simulation

Longitudinal strain in the post-peak regime



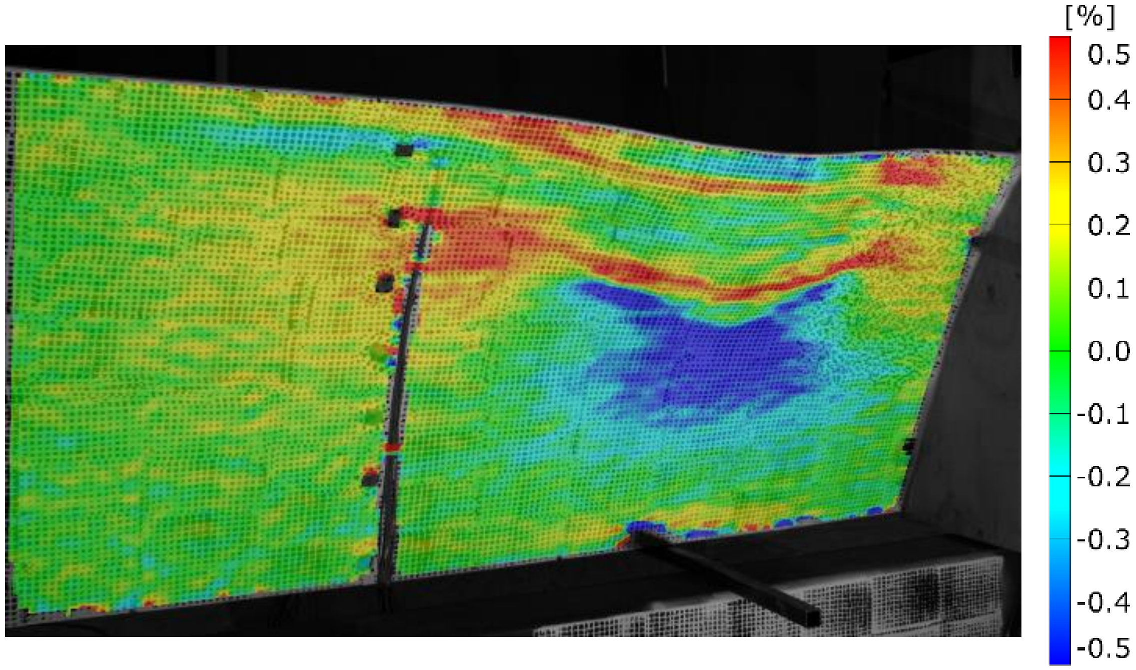
DIC measurement



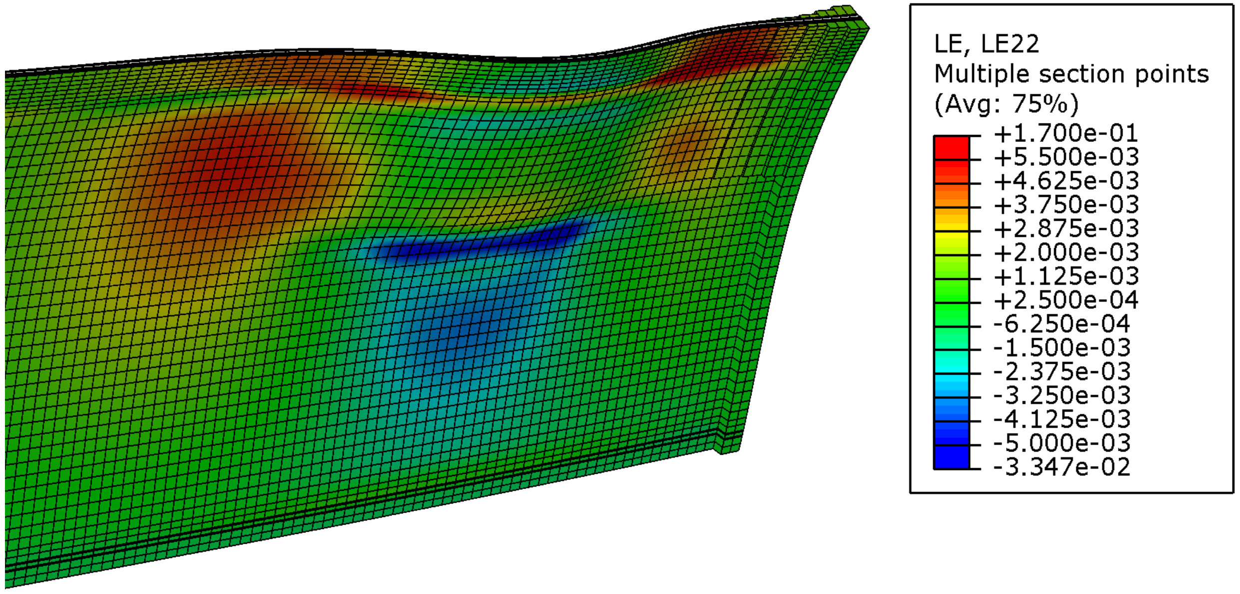
FE simulation

Comparison between DIC measurement and FE simulation

Transverse strain in the post-peak regime

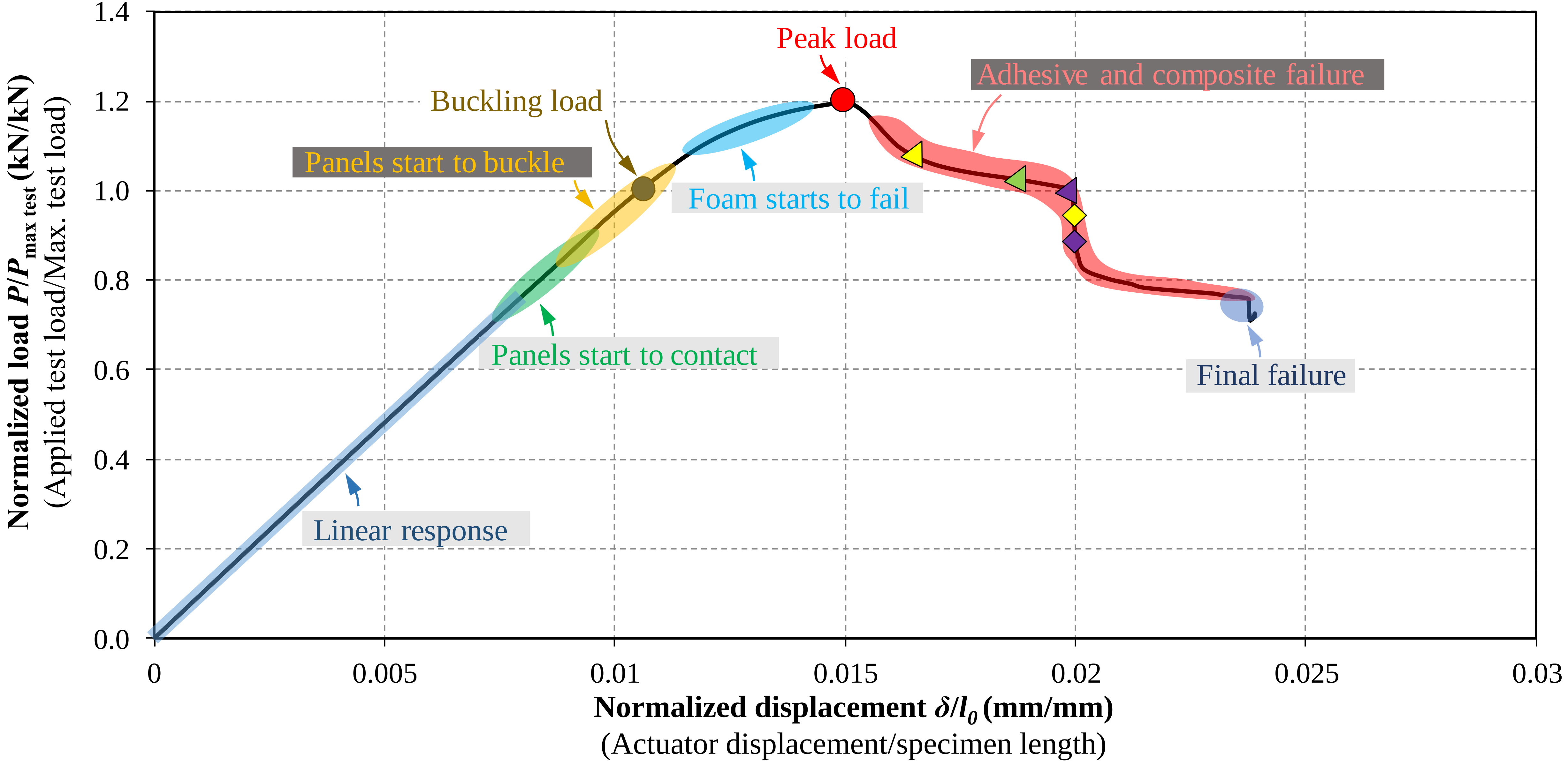


DIC measurement

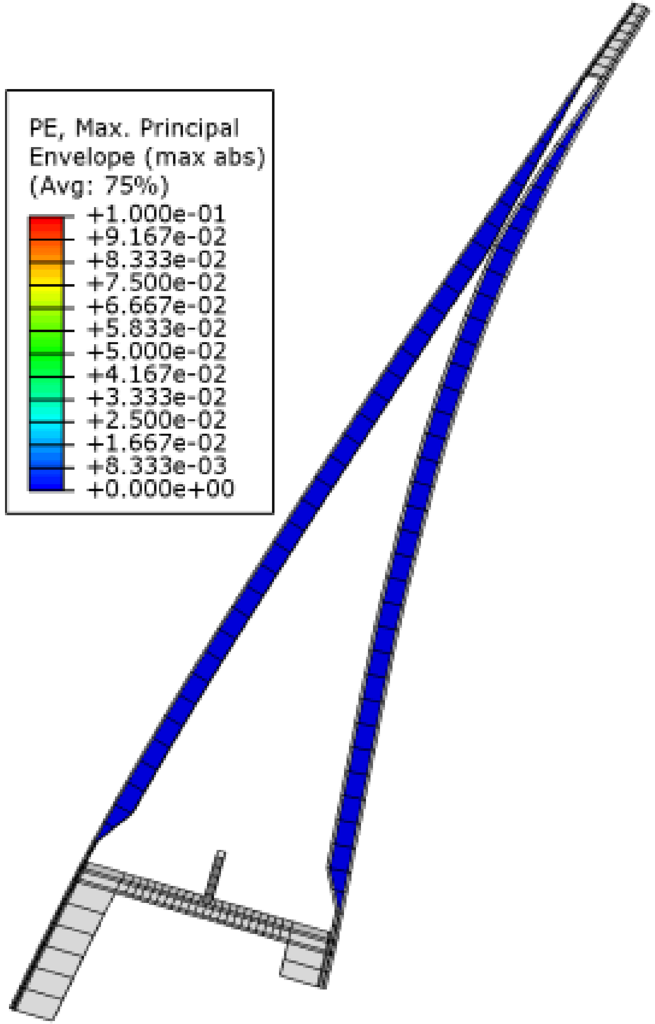


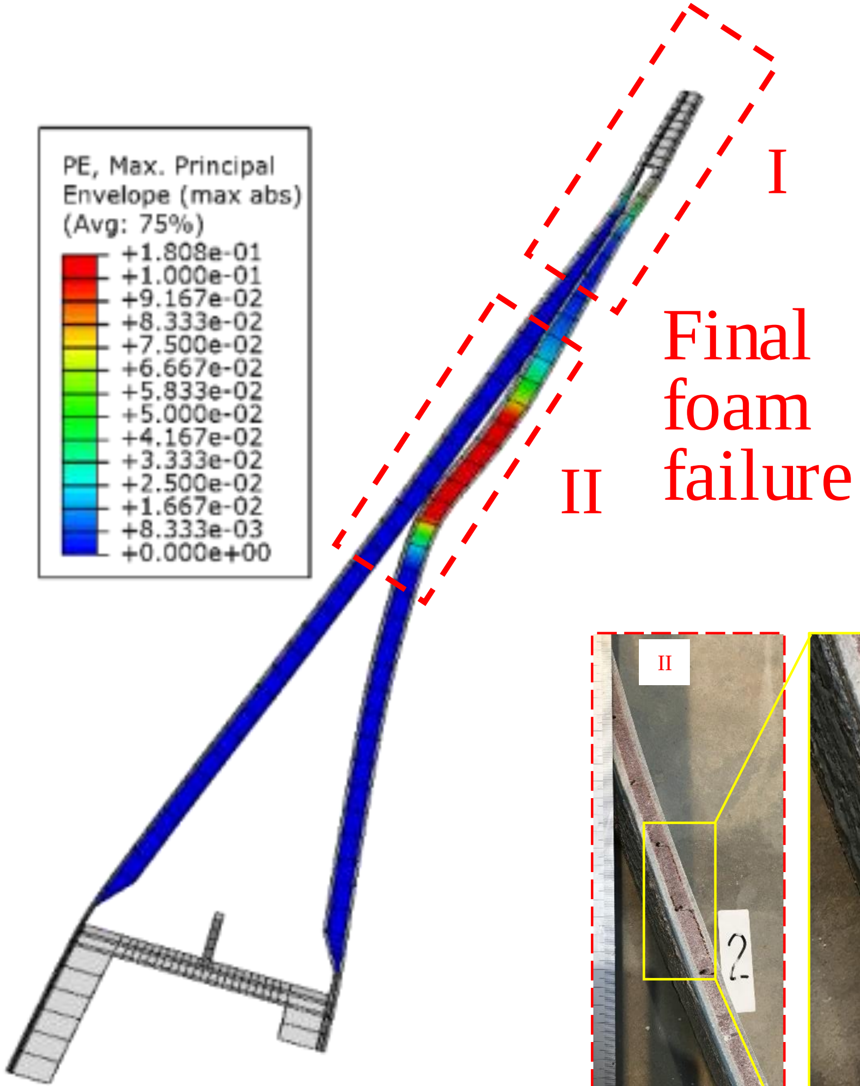
FE simulation

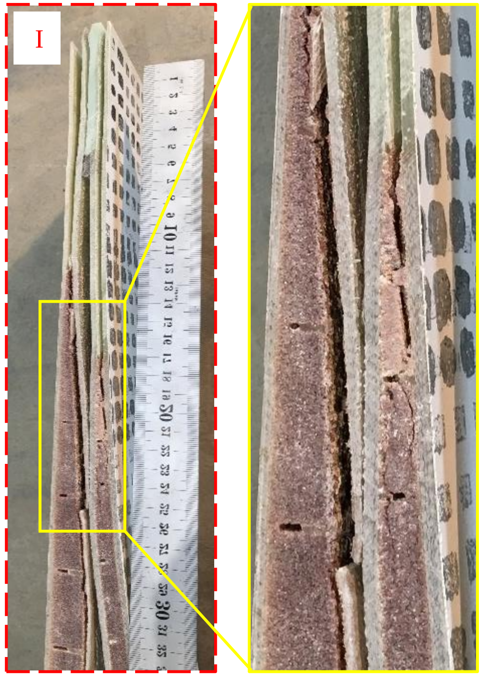
Failure sequence

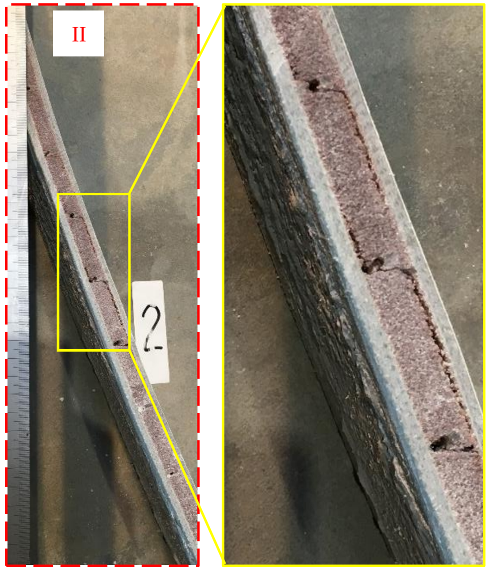


Failure prediction – Foam failure

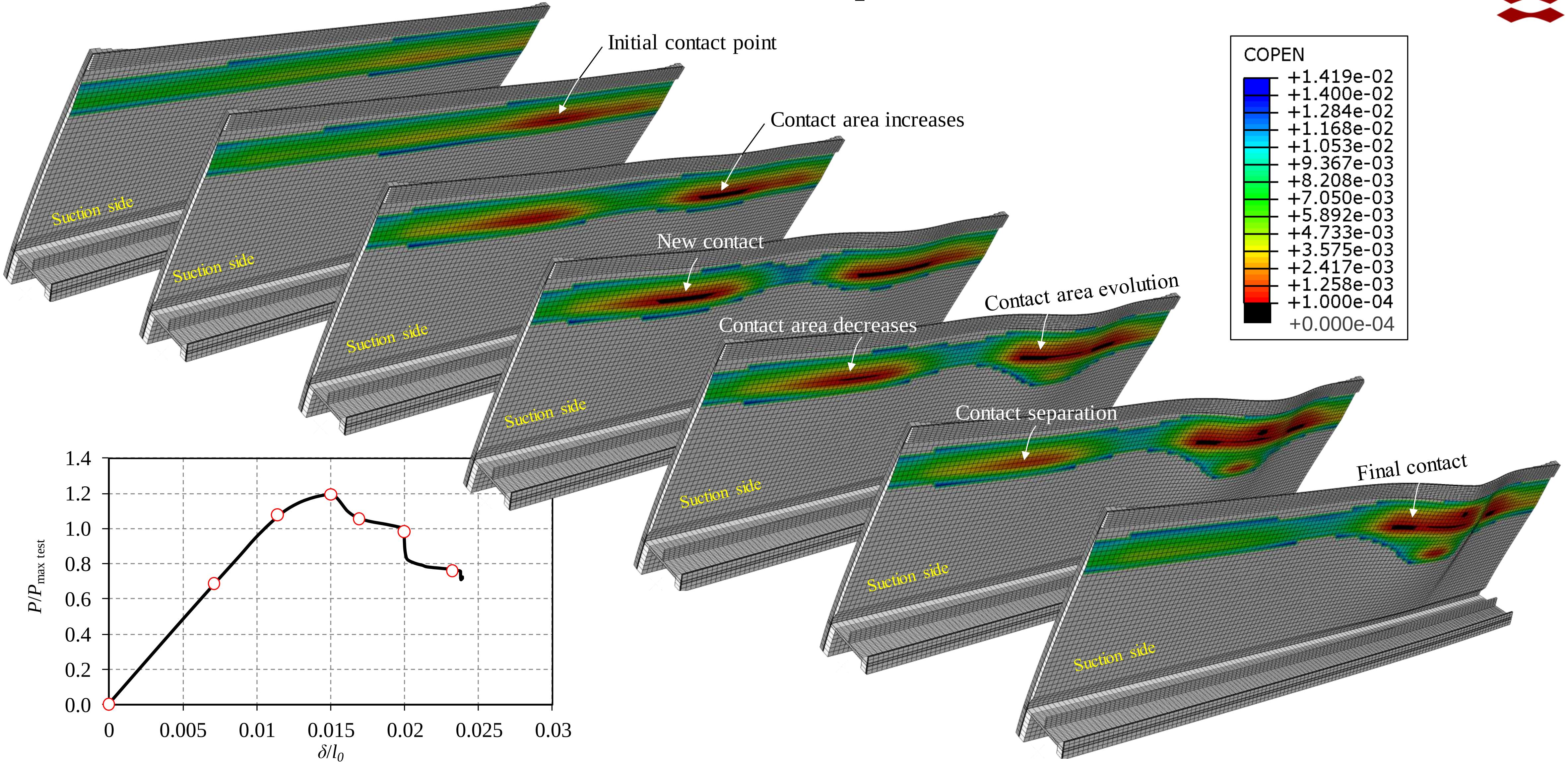






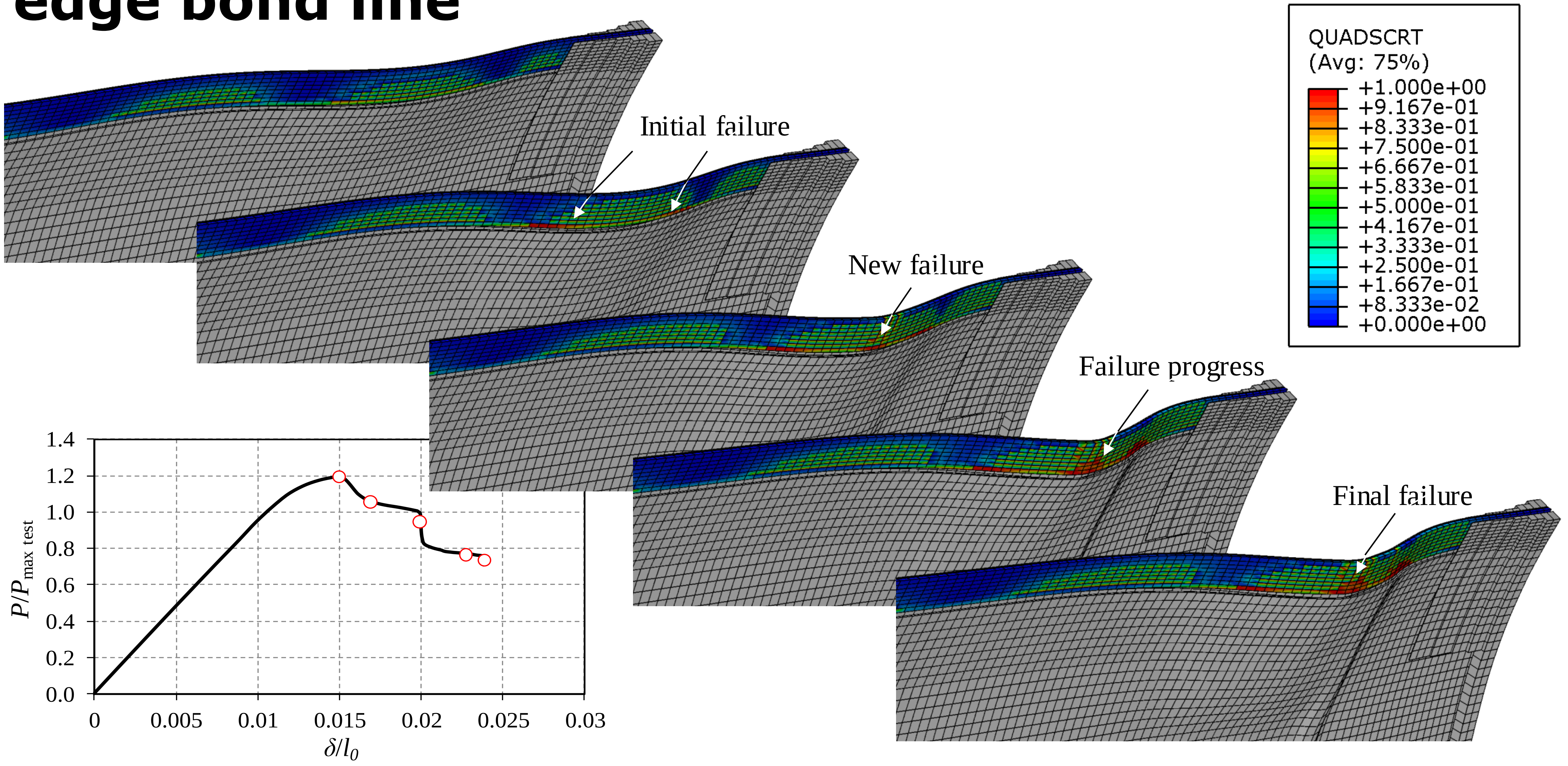


Contact status of sandwich panels

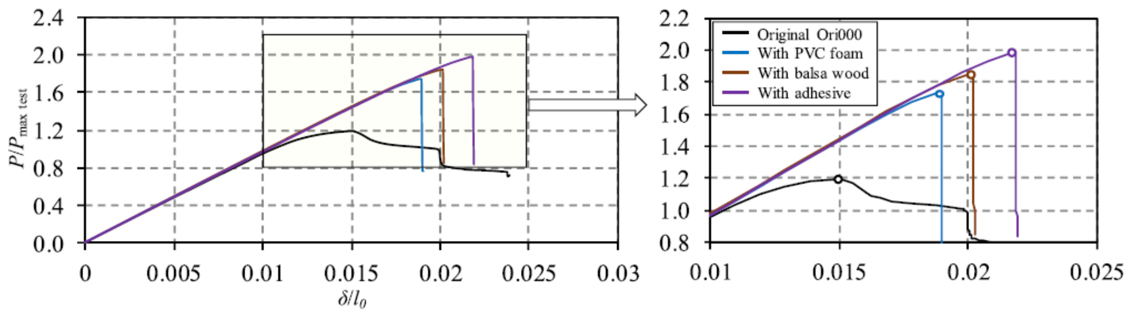


The panel at pressure side is removed from the figures

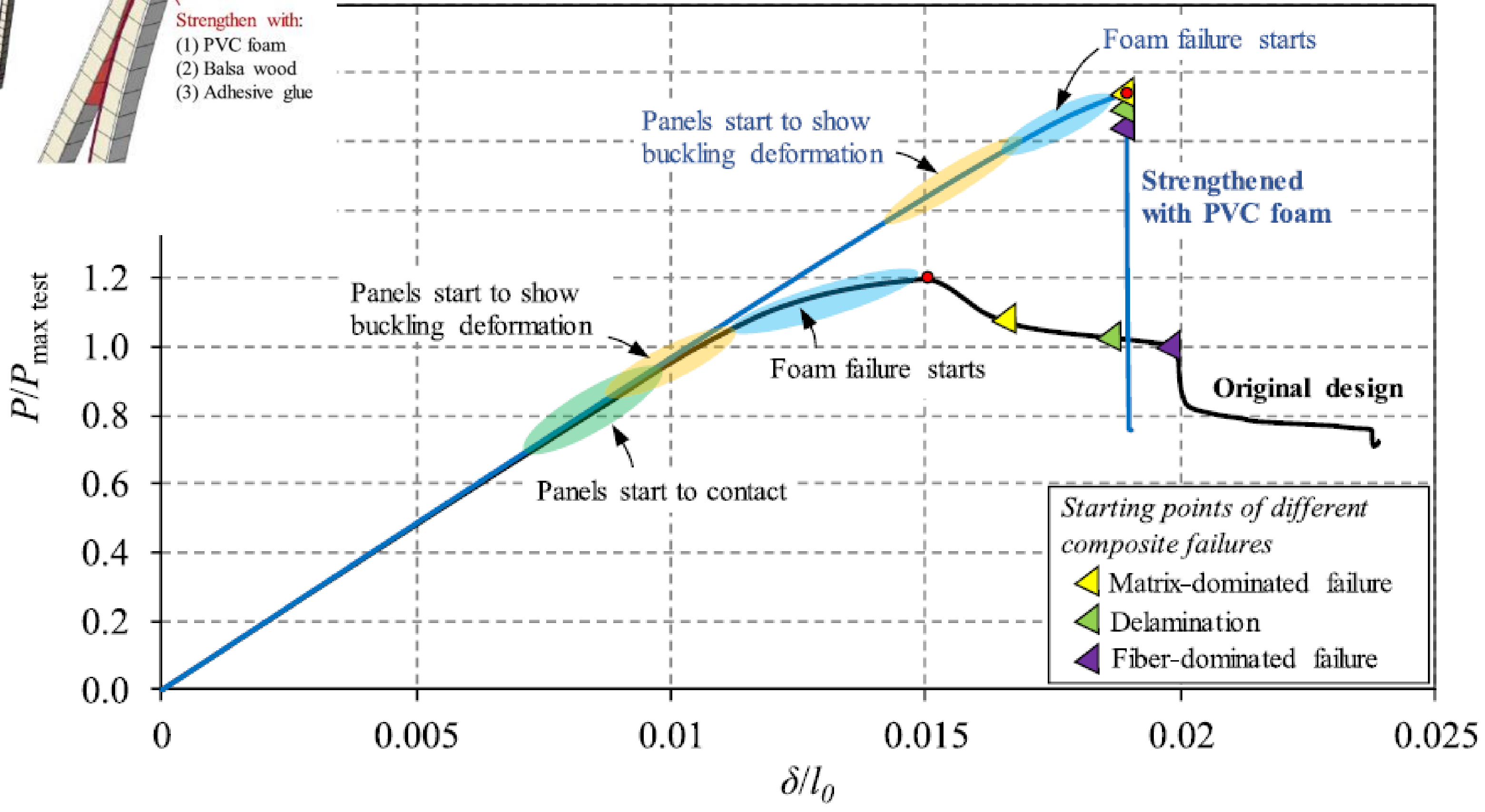
Failure prediction – Adhesive failure at trailing edge bond line



Reinforcement of trailing edge region



- Failure is now predicted to happen at a 45% higher load



Conclusions and future study

- Subcomponent testing provides a new opportunity to investigate structural response of large wind turbine blades in an efficient way.

- The proposed FE modeling techniques show good capability to predict progressive failure of trailing edge section with multiple failure modes.

- The failure process of the trailing edge section is buckling driven. The contact status between two sandwich panels affects the failure process considerably.

- Foam failure starts before the peak load, while adhesive failure and composite failure occur in the post-peak regime.

- Can we relay on structural models when we have:
  - Demonstrated that the global response is modelled correct
  - Verified that failure at critical regions will happen at higher strain levels than seen in operation

Acknowledgements

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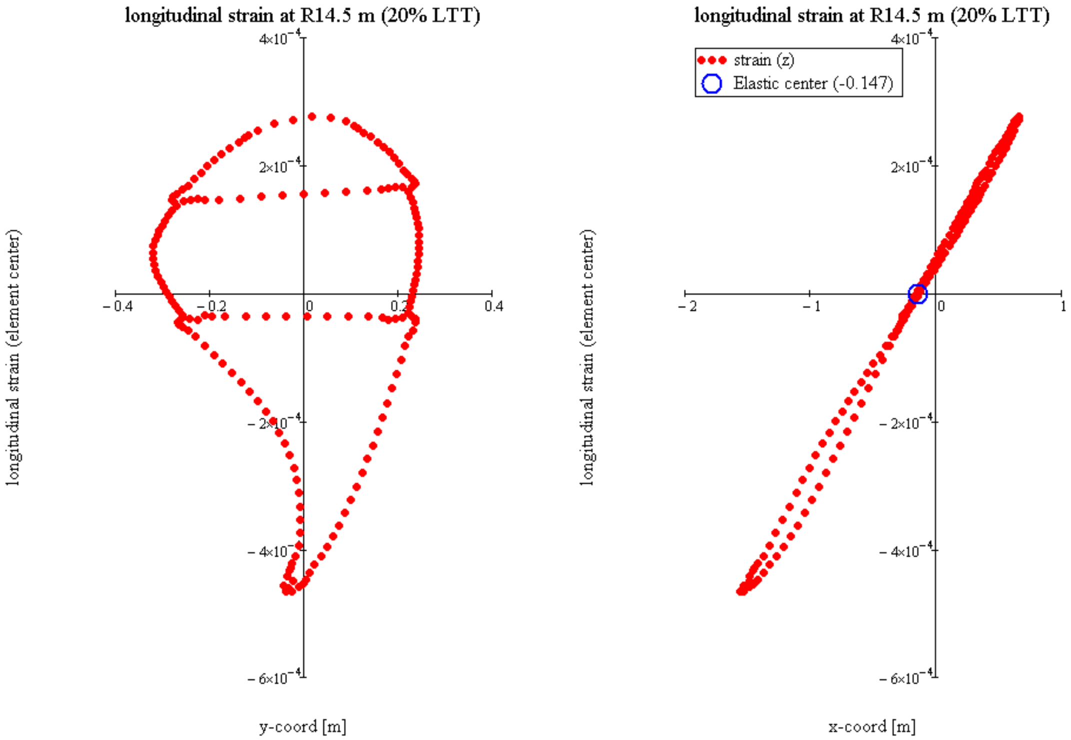
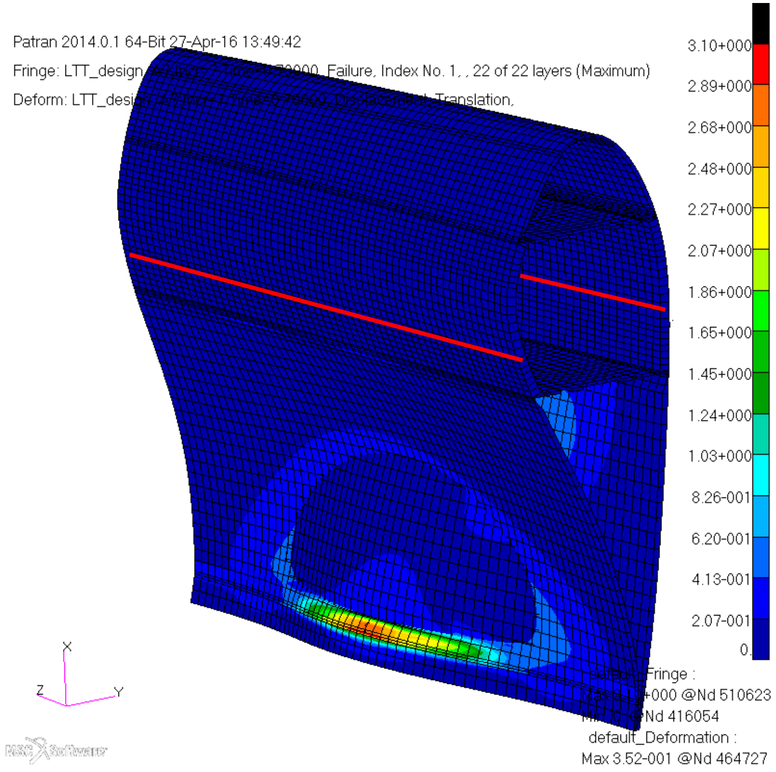
- DTU Large Scale Facility is built by Dansk Halbyggeri A/S with the Danish Building and Property Agency as owner.

Numerical response of the SSP blade - strain and failure mode

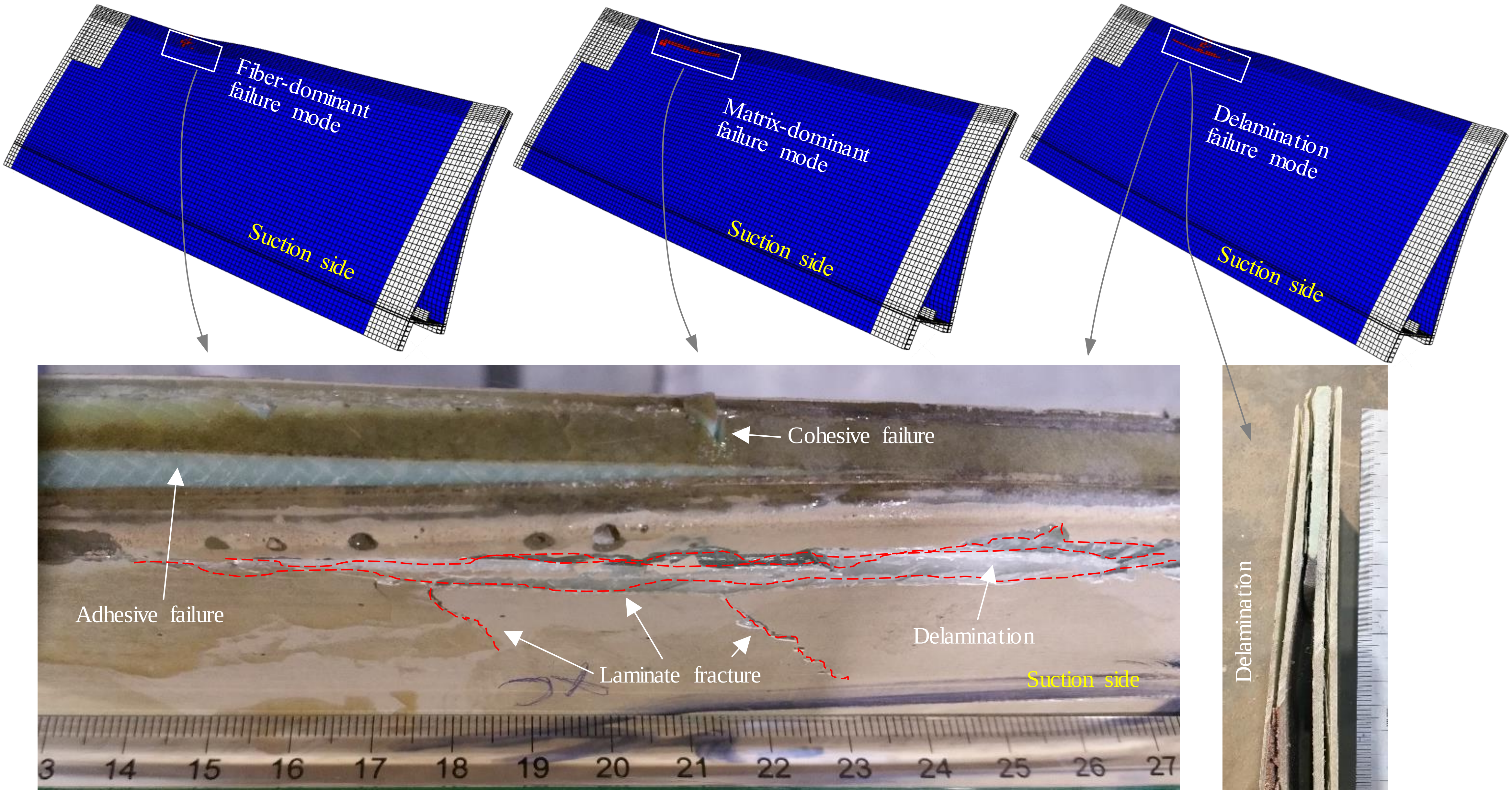
Longitudinal strain and location of elastic center at 20% of the certification load in LTT



At failure computed via Tsai-Wu



Failure prediction – Composite failure (TE region)



Failure prediction – Composite failure (sandwich skin)